Market services productivity across Europe and the US

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SUMMARY

Since the mid-1990s, market services have positively influenced labor productivity growth in the US, but not in most European countries. We analyze these cross-country differences in growth dynamics using industry-level measures of output, inputs, and multifactor productivity (MFP) from the new EU KLEMS database. We find that using detailed data has important implications for empirical analysis of policy influences on growth. Increased investment in information and communication technology (ICT) capital and growth in human capital contributed substantially to labor productivity growth in market services across all European countries and the US. However, countries differ most strongly in the rates of efficiency improvement in the use of inputs. We find no evidence of an externality-driven relationship between such efficiency changes and the growth of ICT use or of employment of university-educated workers. We also find that entry liberalization has been beneficial for productivity growth in telecommunications, but not in other service industries.

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1. INTRODUCTION

Labor productivity growth in the European Union has been substantially slower than in the United States since the mid-1990s. The prospects for Europe to become the most dynamic region of the world in the near future, as established in the Lisbon Agenda, therefore seem to be dim. Table 1 summarizes labor productivity growth across Europe and the US. Even though productivity growth slowed down for the European Union-15 as a whole, this table shows that European performance has not been universally poor.[1] Countries like Austria, Finland and the UK showed much

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[1] The EU-15 refers to all member states before the May 2004 Accession Round. In this paper we do not address the performance of the ten new member states, even though those are part of the EU KLEMS database. Also, in the remainder of the paper we exclude five EU-15 countries from our analysis, i.e. Greece, Ireland, Luxembourg, Portugal and Sweden. The latter countries had to be excluded from the measures of capital and MFP in this paper, because series adequate for growth accounting at the industry level are still missing for the whole of the period 1980–2004. In 2005, these 10 European countries made up 92% of GDP in the EU-15 and 83% of GDP in the EU-25.

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Table 1. Growth rates of GDP per hour worked in European countries and the US, 1980–2006 (average annual growth in %)

	1980–1995	1995–2006
EU-15	2.3	1.4
United States	1.3	2.2
Austria	2.4	2.3
Belgium	2.0	1.4
Denmark	2.5	1.2
Finland	3.0	2.5
France	2.5	1.8
Germany	2.4	1.7
Greece	0.9	2.5
Ireland	3.6	4.2
Italy	2.1	0.4
Luxembourg	2.6	1.9
Netherlands	1.7	1.5
Portugal	2.1	1.7
Spain	3.0	–0.2
Sweden	1.3	2.5
United Kingdom	2.6	2.0
Average of 15 EU countries	2.3	1.8
Standard deviation	0.7	1.0

Notes: Countries that were members of EU-15 before 1 May 2004.

Source: GGDC/TCB Total Economy Database, January 2007, www.ggdc.net

better performance than laggard countries such as Italy and Spain. This raises the broader question of what is driving cross-country differences in productivity growth. By now, it is well known that market services have been the major driver of strong US labor productivity growth since the 1990s (Triplett and Bosworth, 2004) and these industries are at the heart of the labor productivity growth differences between the EU-15 and the US (van Ark *et al.*, 2003, 2008; Blanchard, 2004). A largely unanswered question is still *why* labor productivity growth in market services has differed across Europe and the US.

The main sources of labor productivity growth are investment in physical and human capital and gains in efficiency, also referred to as multifactor productivity (MFP) growth. In this paper, we will provide a detailed accounting of the importance of these sources of labor productivity growth in service industries. For this purpose we make use of the recent release of the EU KLEMS database, which provides a comprehensive overview of output, inputs and productivity at the industry level for a large set of European countries and the US.[2] Our focus on market services should prove particularly useful, not only because the US experience shows that it can be a

[2] The EU KLEMS database is the product of a joint research project, funded by the European Commission, Research Directorate General, in which the Groningen Growth and Development Centre at the University of Groningen is one of the key collaborators. The empirical work in this paper is mostly based on the database released in March 2007, which is freely available at www.euklems.net, described in Timmer *et al.* (2007a).

substantial source of growth, but also because services are amongst the most intensive users of new technologies (in particular ICT) and skilled labor. This puts the developments in market services at the heart of the Lisbon Agenda aimed at creating a dynamic knowledge-based economy, and deserving of further study. If it is true that the growth effects of investment in skills and ICT differ strongly across countries, this should show up most clearly in a study of market services.

After analyzing the sources of labor productivity growth, we undertake an analysis of factors driving technological change and efficiency gains. Aghion and Howitt (2006) suggest that the post-World War II catch-up of European economies to the US has slowed down recently as the technology gap with the US has narrowed. Policies and institutions which facilitated imitation of technologies in the past are not well suited for growth close to the technology frontier. The latter should be based on innovation in a competitive market environment, rooted in a country's own resources such as skilled labor and research and development. The growth-policy recommendations in the Sapir report (Sapir *et al.*, 2004) are in large part based on this line of argument, supported by two key empirical studies. First, Vandenbussche, Aghion and Méghir (2006) show that economies with more university-educated workers show faster MFP growth, in particular when they are close to the technology frontier. Second, Nicoletti and Scarpetta (2003) show that lowering entry barriers stimulates MFP growth. However, their findings are mostly limited to manufacturing industries, which begs the question whether such effects can also be found in market services. This is all the more important since many of the most highly regulated industries today are in market services (Conway and Nicoletti, 2006) and because many of the policy initiatives for regulatory reform focus on opening up of services markets, in particular the EU Services Directive.

The main contribution of this paper is that we address these issues using the new EU KLEMS database. This database contains novel measures of the skill distribution of the workforce and the composition of investment. It makes it possible to accurately measure and analyze the role of high-skilled labor and investment in ICT-capital for labor productivity growth at a detailed industry level. In Section 2, we show that growth differences in market services closely mirror aggregate growth differences across countries. We find that the use of ICT and university-educated workers contributes substantially to labor productivity growth in market services in all European countries and in the US. However, most of the cross-country growth differences are not due to differences in the pace of investment in ICT and human capital. Instead, differences in efficiency gains are the key factor in cross-country differences in labor productivity growth in market services (Section 3). We cannot find any evidence of externalities to the use of ICT and university-educated workers which might explain differences in efficiency gains across countries. As such, our results regarding the effect of human capital stand in contrast to the findings of Vandenbussche *et al.* (2006). We show that this can be traced to the use of more sophisticated productivity data and our industry-level focus. Furthermore, we find that lower regulatory barriers to entry in post and telecommunications have stimulated MFP growth which extends the findings by Nicoletti and Scarpetta (2003) to the services sector. This illustrates the importance of a detailed industry focus. It also provides support for further liberalization, not only within countries, but also across borders as envisaged in the EU Services Directive. However, although our evidence is suggestive of a role for product market liberalization to improve market services productivity growth, it must be treated with caution as we do not find similar supportive evidence for other services industries. Section 5 concludes.

2. MARKET SERVICES AND AGGREGATE GROWTH

Ever since the work by Baumol and Bowen (1966) on the cost disease hypothesis in cultural arts, economic growth in advanced countries is presumed to suffer from slow productivity growth in services. In essence, Baumol's cost disease states that productivity improvements in services are less likely than in the goods-producing industries because many services are inherently labor-intensive, which makes it difficult to substitute labor for capital (Baumol, 1967). As services make up an increasing share of the economy as countries grow richer, a decline in aggregate productivity growth would be inevitable. It turns out, however, that the cost disease hypothesis no longer has much validity at least for the market services sector in the United States, which broadly includes trade, transportation, communication, financial, business and personal services. While the share of market services in the US increased from 37 to 44% between 1980 and 2004, labor productivity growth accelerated from 1.4% from 1980–1995 to 3.3% from 1995–2004 (see Table 2).[3] In a seminal study looking in detail at the productivity performance of individual service industries in the US, Triplett and Bosworth (2006) show that since 1995, 15 out of 22 two-digit services industries experienced an acceleration in labor productivity that at least equalled the economy-wide average. Hence the authors titled their study 'Baumol's Disease has been cured.' Most European countries, however, still seem to suffer from Baumol's disease. While the share of market services in nominal GDP in Europe has been steadily increasing from on average 34% of GDP in 1980 to 41% in 2004, labor productivity growth rates in European market services have been slow and declining in most cases.[4] Only the Netherlands and the UK recorded accelerating productivity growth in market services after 1995 (see Table 2).

Before proceeding we need to provide a more precise measure of the importance of market services in accounting for the trend in aggregate labor productivity growth.

[3] Market services as defined in this study include nine industries, see Appendix Table 1 for precise definitions. The increase in the GDP share of market services is the result of a number of interacting forces (Schettkat and Yokarini, 2006). First, a high income elasticity for services and an increase in per capita income lead to higher demand for services in general. In addition, there is an increasing marketization of traditional household production activities (Freeman and Schettkat, 2005). Finally, there is a tendency for outsourcing of business, trade and transport activities by firms boosting business demand for market services.

[4] As indicated in footnote 1, the EU-average in the remainder of this paper relates to 10 of the 15 EU countries, excluding Greece, Ireland, Luxembourg, Portugal and Sweden.

Table 2. Share in GDP and average annual labor productivity growth in European countries and the US, market services, 1980–2004 (%)

	Share of market services in GDP (%)			Growth of value added per hour worked	
	1980	1995	2004	1980–1995	1995–2004
Austria	37	40	43	2.1	0.7
Belgium	32	40	44	1.4	1.2
Denmark	34	38	40	3.0	0.9
Finland	30	34	36	2.5	1.7
France	36	38	41	1.9	1.3
Germany	32	38	40	2.3	0.8
Italy	36	40	42	0.6	0.3
Netherlands	34	42	46	0.3	2.4
Spain	31	38	41	1.0	0.4
UK	33	41	49	1.9	2.5
US	37	41	44	1.4	3.3
Average	34	39	42	1.7	1.4
Standard deviation	2.4	2.2	3.3	0.8	1.0

Source: EU KLEMS database, March 2007 (http://www.euklems.net), described in Timmer *et al.* (2007).

The contributions of market services to aggregate labor productivity can be calculated using a shift-share approach. Following this approach the contribution of an industry to aggregate productivity growth is measured by weighting its labor productivity growth rate by its share in aggregate value added. Figure 1 summarizes the relative contributions of market services and the other industries (including manufacturing, mining, utilities and agriculture) to labor productivity growth in the market economy for each country in the period 1995–2004.[5] The countries are ranked according to total market economy productivity growth ranging from the highest growth rate in Finland to the lowest growth rate in Spain.[6] It appears that the divergence in market economy productivity growth is mainly due to differences in the contribution of market services, which is highest in fast-growing economies such as Finland, the US, the Netherlands and the UK, and close to zero in Germany, Italy and Spain. This confirms the results from recent studies for the US by Jorgenson, Ho and Stiroh (2005) and Bosworth and Triplett (2007) which indicate that market services are the most important driver of the American growth resurgence. The differentiating role of market services also confirms our previous studies on the growth differential

[5] Market economy excludes health (ISIC industry N), education (ISIC M), private households with employed persons (ISIC P) and government sectors (ISIC L). We also exclude real estate (ISIC 70), because output in this industry mostly reflects imputed housing rents rather than sales of firms. The measurement problems in the public services are more substantial than in market services, and in several cases (in particular for government) the output growth is measured using input growth. Still, labor productivity growth measures for non-market services tend to be somewhat higher for the EU than for the US, so that the market economy productivity measures show an even larger gap between the EU and the US since 1995 and in particular since 2000, than the measures for the aggregate economy.

[6] Strong productivity growth in other industries in Finland is driven primarily by growth in IT-goods production (Daveri and Silva, 2004). Other countries covered in this study have a much smaller IT-producing sector.

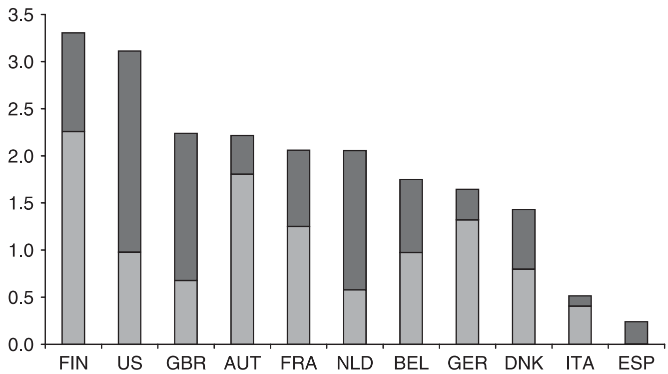

Figure 1. Contribution of market services (dark) and other industries (light) to market economy labor productivity growth in Europe and US, 1995–2004

Notes: Following Stiroh (2002) aggregate labor productivity growth can be written as:

$$\ln \frac{VA_t/H_t}{VA_{t-1}/H_{t-1}} = \sum_i \bar{v}_i^{VA} \ln \frac{VA_{i,t}/H_{i,t}}{VA_{i,t-1}/H_{i,t-1}} + \left(\sum_i \bar{v}_i^{VA} \ln \frac{H_{i,t}}{H_{i,t-1}} - \ln \frac{H_t}{H_{t-1}} \right)$$

where VA and H denote gross value added and hours worked respectively, and $\bar{v}_i^{VA}$ is the two-period average share of industry i in aggregate value added. The contribution of an industry to aggregate productivity growth is measured by weighting its labor productivity growth rate by its share in aggregate value added. The term in brackets is the reallocation of hours. It reflects differences in the share of an industry in aggregate value added and its share in aggregate hours worked. The reallocation term is positive if employment shifts from low productivity industries towards high productivity industries. 'other industries' also includes the reallocation-term.

Source: EU KLEMS database, March 2007 (http://www.euklems.net), described in Timmer *et al.* (2007a).

between Europe and the United States (O'Mahony and van Ark, 2003; Losch, 2006; Inklaar, Timmer and van Ark, 2007).

A more in-depth focus on the market services sector reveals that growth differences are particularly large in retail and wholesale trade and financial services. This raises the question to what extent the differences in performance across Europe are a statistical artefact due to differences in measurement methods by national statistical institutes, as for example suggested in a report of the European Commission (2004). Based on a survey of the current state of services output measurement practices we conclude that for many market service industries, output measures in the National Accounts should give a fairly accurate – albeit not perfect – internationally comparable picture of developments (see discussion in Appendix 1).

3. THE GROWING ROLE OF SKILLS AND ICT-CAPITAL IN GROWTH

It has often been stated that growth in today's knowledge economy is strongly driven by an increasing use of skills and ICT-capital in the so-called knowledge economy. In this section we use a growth accounting methodology to measure the relative contributions of various capital assets and labor types to growth in market services. Section 3.1 introduces the basic data source for this paper, the EU KLEMS database. In Section 3.2 we discuss recent trends in investment in ICT and non-ICT assets in market services across Europe and the US. This is followed by an analysis of the developments in the use of skilled labor over the past decades (Section 3.3). Based on these input measures, a decomposition of labor productivity growth in market services is provided in Section 3.4. We show that investment in ICT and the use of skilled labor are important drivers of labor productivity growth in all countries. On average, they account for a large part of the growth in all European countries. However, *differences* in investment rates and the use of skilled labor cannot fully explain the *differences* across countries in labor productivity growth. This suggests that the fastest growers are particularly characterised by their more efficient use of inputs as measured by multifactor productivity (MFP). The determinants of MFP growth are analysed in more detail in Section 4.

3.1. EU KLEMS database and growth accounting methodology

In this study we exploit a new growth accounts database, called EU KLEMS.[7] This database has been constructed with the explicit aim of providing internationally comparable series on output, inputs and productivity by industry within a consistent framework for a large set of European countries and the United States. In this database, various sets of inputs are distinguished: capital (K), labor (L), Energy (E), Materials (M) and Services (S). Accurate measures of labor and capital input contributions to growth are based on a breakdown of aggregate hours worked and aggregate capital stock into various components. Hours worked are cross-classified by educational attainment, gender and age (to proxy for work experience) into 18 labor categories to account for differences in the productivity of various labor types, such as high- versus low-skilled labor. Thus labor input measures in EU KLEMS take account of changes in the skill-level of the labor force. Similarly, capital stock measures are broken down into different asset types to study the impact of the increasing use of ICT assets. We make a distinction between three ICT assets (office and computing equipment, communication equipment and software) and three non-ICT assets (transport equipment, other machinery and equipment and non-residential structures).[8]

The EU KLEMS database provides a long time-series going back to 1970 through linking of National Accounts data series from different release vintages. National Accounts series are further subdivided into the industry, labor and capital detail on the basis of additional secondary data sources. For example, industry detail for output and labor input (employment and hours) series is obtained from industry surveys. For a breakdown of various labor categories, additional sources are used, such as Labour Force Surveys, which are available on an annual basis for most countries. Separate

[7] This database is publicly available at www.euklems.net and described in Timmer *et al.* (2007a).

[8] Residential capital is excluded from the analysis here to focus on assets in the market economy. Investment in residential buildings is almost exclusively concentrated in the real estate industry, which is excluded in this study.

series on investment particularly in computers and communication equipment are normally not provided in the National Accounts, so that a breakdown of investment into various asset types was done using additional information from input–output tables and investment surveys. Further details on the sources and methods used for each country can be found in Appendix 2 and Timmer *et al.* (2007a).

To assess the contribution of the various inputs to aggregate growth, we apply the growth accounting framework as developed by Jorgenson and associates (see, for example, Jorgenson, Ho and Stiroh, 2005). For the purpose of this paper we will decompose the growth of labor productivity (value added per hour worked) into the contribution of ICT capital services, non-ICT capital services, labor services and multifactor productivity (see Box 1). The growth contribution of each input is calculated as the growth rate of the input per hour worked multiplied by the share of the input in value added (see Appendix 2 for a more formal description).

Box 1. What does multifactor productivity growth measure?

Multifactor productivity (MFP) growth is measured as the difference between the volume growth of outputs and the volume growth of inputs. As such, it captures increases in the amount of output that can be produced by a given quantity of inputs. Put alternatively, it captures the reduction in input costs to produce a given amount of output. Many factors may cause changes in MFP growth. Under strict neo-classical assumptions, MFP growth measures disembodied technological change. In practice, measured MFP includes a range of other effects. First, in addition to technical innovation it also includes the effects from organizational and institutional change. For example, the successful reorganization of a business to streamline the production process will lead to higher MFP growth. Second, MFP also captures changes in returns to scale. For example, there is some evidence that scale is important for realising productivity growth in retail trade, possibly because of the large outlays required for modern inventory management systems. Foster, Haltiwanger and Krizan (2006) show that much of US productivity growth in retail trade is due to the spread of national chains. If a firm originally operates below its minimum efficient scale, increasing production will lead to an increase in measured MFP. Third, MFP measures pick up any deviations from the neo-classical assumption that marginal costs reflect marginal revenues. If, on the one hand, there are externalities related to investments in ICT in network industries this will increase MFP. On the other hand, when ICT investments have been driven more by herd-behavior than by economic fundamentals, MFP is underestimated and the contributions of ICT investment to growth are overestimated. Fourth, being a residual measure, MFP growth also includes the effects from unmeasured inputs, such as research and development and other intangible investments. Finally, MFP includes measurement errors, such as mismeasurement of the quality change of new services products, or of high-tech inputs. We partly address this problem by using deflators for IT-investment that correct for quality change. In Appendix 1 we discuss the – in our view – limited degree of mismeasurement of services output.

In this paper we use MFP measured at the industry-level, not at the firm-level. Importantly, industry-level MFP reflects not only the average change in MFP of each firm within the industry, but also includes the effects of reallocation of market shares across firms. For example, MFP growth in a particular industry might increase through a shake out of the least productive firms, for example, because of increased competitive pressure after liberalizing domestic markets. Similarly the privatization of public firms might lead to a reduction in input use. It should be stressed that all effects on measured MFP discussed here can be broadly summarized as 'improvements in efficiency', as they improve the productivity with which inputs are being used within the industry. See Hulten (2001) for a more extensive discussion of the MFP concept.

3.2. The role of investment in ICT and non-ICT capital

The availability of investment series by asset type and by industry is one of the unique characteristics of the EU KLEMS database, allowing for a detailed analysis of investment in specific types of assets by individual industry. In Table 3 we provide the

Table 3. Investment-to-value-added ratios for ICT- and non-ICT capital, market services in Europe and the US, averages over 1980–1995 and 1995–2004

	1980–1995		1995–2004	
	ICT	Non-ICT	ICT	Non-ICT
Austria	3.6	16.8	4.2	15.9
Belgium	n.a.	n.a.	n.a.	n.a.
Denmark	5.8	15.1	6.2	16.2
Finland	4.2	19.6	5.2	11.8
France	2.9	12.8	4.1	12.0
Germany	2.8	11.6	3.9	14.0
Italy	3.3	19.4	3.4	18.4
Netherlands	3.8	13.4	4.8	11.6
Spain	4.4	11.5	4.5	15.3
UK	4.0	14.9	6.6	13.0
US	4.2	9.9	5.9	8.6
Average	3.9	14.5	4.9	13.7
Standard deviation	0.9	3.3	1.1	2.8

Notes: Ratios of nominal gross fixed capital formation over nominal value added in market services. The figures for Germany 1980–1995 refer to West Germany 1980–1991. Figures for Italy exclude business services (ISIC 71–74).

Source: EU KLEMS database, March 2007 (http://www.euklems.net), described in Timmer *et al.* (2007).

shares of investment expenditure in gross value added in market services for each country. The trend of increasing investment in ICT capital in market services stands out clearly. On average, over all countries, the ICT investment to value added ratio increased from 3.9% during 1980–1995 to 4.9% during 1995–2004. The latter period includes the ICT investment boom in the run-up to the millennium as well as the post-2000 bust. Strikingly, ICT investment rates in 2004 are back to the levels of the beginning of the 1990s, suggesting that expenditures on ICT assets have become a routine and stable part of firms' strategies. It should be stressed though that expenditures on non-ICT assets are still at least double or triple the outlays for ICT assets. Even in market services, which are the most intensive users of ICT, investment in non-ICT related equipment and non-residential structures are still dominant. Table 3 also shows that there is a substantial variation in investment rates across countries. For example, ICT investment rates are the highest in Denmark, Netherlands, UK and the US in the period 1995–2004 but much lower in large continental European countries such as France, Germany, Italy and Spain. Investment in traditional (non-ICT) assets is highest in Austria, Denmark and Spain. This raises the question to what extent differences in investment rates can explain differences in labor productivity growth rates.

To answer this question one has to transform the investment flows into a measure of capital services. Capital services measure the flow of services of the capital stock which is being used during a particular period of time. To measure capital services on the basis of investment series, a number of procedural steps have to be taken. First, nominal investment series are deflated and accumulated into stock estimates using the Perpetual Inventory Method (see Appendix 2 for details). The deflators for IT-hardware reflect the rapid changes in quality (see Box 2 on ICT investment deflators). The capital stocks for the different assets are then aggregated on the basis of the user cost of each asset to form capital service flows.

The user cost approach is crucial for the analysis of the contribution of capital to output growth. It was introduced by Jorgenson and Griliches (1967) and is based on the assumption that marginal costs reflect marginal productivity. A simple example may illustrate this approach. Suppose that a firm uses a computer and a building for one year. If the annual costs of using one euro of computers is higher than the cost of using one euro of buildings, computers have a higher marginal productivity, and this should be accounted for. There are various reasons why the cost of computers is higher than for buildings. While computers may typically be scrapped after five or six years, buildings may provide services for several decades. Besides, prices of new computers are rapidly declining while those of buildings do not in normal circumstances. This decline in value of computers entails a cost. Typically, the user cost of computers is 50 to 60% of the investment price, while that of buildings is less than 10%. Therefore the growth in the computer capital stock gets a heavier weight in calculating capital services than the growth in the building stock. Appendix 2 explains the derivation of the capital services estimates in more detail.

Box 2. ICT investment deflators

To transform the nominal investment series into volumes, price deflators for each asset type are needed. Price measurement for ICT assets has been an important research topic in recent years, as the quality of those capital goods has been rapidly increasing. Until recently, large differences existed in the methodology to obtain deflators for ICT equipment between countries, and the use of a single harmonized deflator across countries was widely advocated and used (Schreyer, 2002; Colecchia and Schreyer, 2002; Timmer and van Ark, 2005). This deflator was based on the US deflators for computer hardware, which were commonly seen as the most advanced in terms of accounting for quality changes using hedonic pricing techniques (Triplett, 2006). However, in recent years, many European countries, such as France, Germany, Netherlands and the UK have made significant progress in either developing and implementing their own quality-adjusted deflators for IT equipment, using high-frequency matched models or hedonic-type deflators, or by using deflators based on adapted price indices from the US Bureau of Economic Analysis. These new deflators typically show price declines of about 10% annually. For those countries (Austria, Belgium, Finland, Spain and Italy) which have not implemented a quality-adjusted investment deflator for computers yet, we continued to use the harmonization procedure suggested by Schreyer (2002).

In Table 4 the contributions of the increase in capital services from ICT and non-ICT assets per hour worked to labor productivity growth are given for the periods 1980–1995 and 1995–2004. Two general trends stand out. First, in the most recent period ICT capital is dominating non-ICT capital as a driver of productivity growth. On average, ICT capital contributes 0.8 percentage points to productivity growth across all countries during 1995–2004, while non-ICT capital contributes only 0.2 percentage points. This might be surprising given the higher investment-to-value added ratios in non-ICT as shown in Table 3, but due to the user-cost approach, the rapid growth in short-lived ICT assets gets a relatively large weight. Still the dominance of ICT is not only due to an increase in the contribution of ICT over time, but to a general decline in the contribution of non-ICT per hour worked in many European countries. This dominance of ICT as a contributor to growth is true for most countries, with the major exception of Spain.[9]

Major differences in the importance of ICT for growth can be found across countries, reflecting the long-run differences in ICT investments. While ICT capital contributes 1.2 percentage points or more to labor productivity growth in Denmark,

[9] Arguably, market services growth in Spain is still heavily reliant on catching-up in non-ICT based technologies.

Table 4. Contribution of ICT and non-ICT capital deepening to labor productivity growth in market services, average annual growth (in percentage points)

	1980–1995		1995–2004	
	ICT-capital	Non-ICT capital	ICT-capital	Non-ICT capital
Austria	0.5	0.4	0.8	0.0
Belgium	0.9	0.3	0.9	0.2
Denmark	1.4	0.2	1.4	–0.5
Finland	0.5	0.4	0.6	–0.7
France	0.4	0.4	0.5	0.3
Germany	0.3	0.6	0.7	0.6
Italy	0.3	0.4	0.2	0.4
Netherlands	0.5	0.1	0.8	0.2
Spain	0.6	0.8	0.5	0.7
UK	0.7	0.6	1.2	0.5
US	0.9	0.4	1.4	0.3
Average	0.7	0.4	0.8	0.2
Standard deviation	0.3	0.2	0.4	0.4

Notes: The figures are a weighted average of ICT and non-ICT capital deepening rates across nine market services industries, where the weight is given by the share of the industry in ICT or non-ICT capital compensation.

Source: EU KLEMS database, March 2007 (http://www.euklems.net), described in Timmer *et al.* (2007).

the UK and the US, contributions are 0.5 percentage points or less in major continental countries such as France, Italy and Spain and there are no signs of catching up. The reason for these seemingly large structural differences are still not very well understood. Conway *et al.* (2006) and Gust and Marquez (2004) suggest that part of these cross-country differences in ICT investment are due to the impact of different regulatory environments, in particular regulations affecting product and labor markets.[10] But much of the cross-country differences remain unexplained.

3.3. The role of changes in labor composition

Another important input in market services which has attracted attention is the use of skilled labor. Technological change has been frequently characterized as skill-biased, especially in knowledge-intensive sectors such as telecommunications, finance and parts of business services.[11] In Table 5 the shares of high-skilled workers in market services employment are given for 1980, 1995 and 2004 for our group of countries (summed over the two other dimensions, gender and age). The table shows that there has been a steady increase in the importance of high-skilled workers over time. Typically, the share of high-skilled workers has doubled or even tripled in the

[10] See also the model by Alesina *et al.* (2005).

[11] See for a skill-taxonomy of industries, Chapter 2 of O'Mahony and van Ark (2003).

Table 5. The share of high-skilled workers in market services employment (%)

	1980	1995	2004
Austria	3.3	7.6	10.9
Belgium	6.7	12.0	15.5
Denmark	2.7	5.8	8.5
Finland	14.6	29.8	30.7
France	6.3	11.9	16.1
Germany	3.7	6.6	8.0
Italy	4.7	7.4	14.1
Netherlands	3.8	8.6	11.2
Spain	5.3	12.1	19.4
UK	8.0	12.8	18.0
US	19.4	26.9	30.6
Average	7.1	12.9	16.6
Standard deviation	5.2	8.1	7.8

Notes: High-skilled workers are defined as those with college education or above (see also footnote 16).

Source: EU KLEMS database, March 2007 (http://www.euklems.net), described in Timmer *et al.* (2007).

past two decades, suggesting an important role for growth in market services. Despite the resurgence of employment growth in continental Europe, the upward trend in the share of high-skilled labor has continued since the mid-1990s (Garibaldi and Mauro, 2002). This finding does not lend support to the popular notion that increases in employment have led to an increase in the share of low-skilled workers in market services. For example, Blanchard (2004) suggested that labor productivity growth declines during periods of increased employment as it is based on employing low-skilled workers, which were previously unemployed. However, the upward trend in the skill-content of the employees reflects the long-run impact of investments made in the educational systems as newcomers on the labor market have had on average more schooling than the existing labor force. This pattern appears true for all service industries, with the largest changes in knowledge-intensive industries like post and telecommunications and finance, and the smallest (but still positive) changes in personal and social services.[12]

As for the case of capital, the productivity of various types of labor, such as low- versus high-skilled labor, will differ and standard aggregate measures of labor input, such as number of persons employed or hours worked, will not account for such differences. In the growth accounting approach, it is assumed that the flow of labor services for each labor type is proportional to hours worked, and workers are paid

[12] The large cross-country differences in the share of high-skilled labor in Table 5 may appear surprising. For example, this share is much lower in Germany than in Spain, the UK or the US. This is due to the problem of lack of precise comparability of skill categories across countries. In the EU KLEMS database high-skilled workers are defined as those with college education or above. However, educational systems within Europe and the US are very different. In particular the different role of vocational schooling systems causes problems of comparability across countries. For example, in Germany vocational training is important to enter many occupations, but this is unknown in the US (see also Koeniger and Leonardi, 2007, p. 89). For time series of MFP in a country, it is most important, however, to use a consistent skill definition over time within each country. This has been the primary aim in the EU KLEMS database. See Mason, O'Leary and Vecchi (2007) for a detailed comparison of skill levels in major European countries.

their marginal productivities. The growth of labor services is then given by the growth rate of hours worked by each labor type, weighted by its share in labor compensation. Typically, a shift in the share of hours worked by low-skilled workers to medium- or high-skilled workers will then lead to a growth of labor services which is bigger than the growth in total hours worked. We refer to this difference as the labor composition effect.[13]

3.4. Sources of labor productivity growth

Based on the developments in labor and capital input measures described above, a decomposition of labor productivity growth in market services industries into the contribution of factor inputs and MFP growth can be made (Table 6). The contributions are given for each country for the periods before and after 1995. The table shows that, for example, in France during the period 1980–1995 annual average labor productivity growth was 1.9%. The increased use of ICT capital per hour worked contributed 0.4 percentage points to this growth. Similarly, non-ICT capital deepening and the changes in the labor composition contributed 0.4 and 0.5 percentage points respectively. The remaining 0.6 percentage points of labor productivity growth were due to improvements in MFP.

Table 6 shows that during 1980–1995, changes in labor composition contributed 0.4 percentage points to labor productivity growth when averaged over all countries. This contribution is mainly caused by an increase in the average skill levels of the employees. The contribution declined, but still remained positive after 1995 (0.2 percentage points on average). In both periods, changes in labor composition were as important for growth as increases in non-ICT capital per hour worked. The foremost conclusion to be drawn from this table is the importance of investments in fixed capital and human capital in driving labor productivity growth during both periods. Averaged over all countries, investment in factor inputs almost fully accounted for labor productivity growth in both periods and changes in MFP were, on average, only minor.

However, when it comes to explaining differences in labor productivity growth between countries, investments in human and physical capital are not of much help. As indicated by the standard deviations in Table 6, cross-country differences in labor composition are generally too small to account for the divergence in labor productivity growth and the same is true for non-ICT capital deepening. While the differences in contributions from ICT are bigger, these can only explain part of the observed growth differences. For example, the difference in the contribution of ICT between

[13] This difference is also known as 'labor quality' in the growth accounting literature (see e.g. Jorgenson, Ho and Stiroh, 2005). However, this terminology has a normative connotation which easily leads to confusion. For example, lower female wages would suggest that hours worked by females have a lower 'quality' than hours worked by males. Instead we prefer to use the more positive concept of 'change in labor composition'.

Table 6. Sources of labor productivity growth in market services in Europe and the US, 1980–1995 and 1995–2004, average annual growth (in percentage points)

	Labor productivity growth	Contribution from:			
		ICT capital deepening	Non-ICT capital deepening	Labor composition change	Multifactor productivity growth
1980–1995					
Austria	2.1	0.5	0.4	0.4	0.7
Belgium	1.4	0.9	0.3	0.5	–0.4
Denmark	3.0	1.4	0.2	0.4	1.0
Finland	2.5	0.5	0.4	0.9	0.7
France	1.9	0.4	0.4	0.5	0.6
Germany	2.3	0.3	0.6	0.2	1.2
Italy	0.6	0.3	0.4	0.2	–0.3
Netherlands	0.3	0.5	0.1	0.2	–0.6
Spain	1.0	0.6	0.8	0.5	–1.0
UK	1.9	0.7	0.6	0.2	0.4
US	1.4	0.9	0.4	0.2	0.0
Average	1.7	0.7	0.4	0.4	0.2
Standard deviation	0.8	0.3	0.2	0.2	0.7
1995–2004					
Austria	0.7	0.8	0.0	0.2	–0.4
Belgium	1.2	0.9	0.2	0.4	–0.3
Denmark	0.9	1.4	–0.1	0.3	–0.7
Finland	1.7	0.6	–0.7	0.0	1.9
France	1.3	0.5	0.3	0.4	0.1
Germany	0.8	0.7	0.6	0.0	–0.6
Italy	0.3	0.2	0.4	0.2	–0.6
Netherlands	2.4	0.8	0.2	0.1	1.3
Spain	0.4	0.5	0.7	0.4	–1.2
UK	2.5	1.2	0.5	0.4	0.4
US	3.3	1.4	0.3	0.3	1.3
Average	1.4	0.8	0.2	0.2	0.1
Standard deviation	1.0	0.4	0.4	0.2	1.0

Notes: The figures are weighted averages of growth rates of inputs and outputs across nine market services industries, where the weight is given by the share of the industry in output or the costs of the relevant input. Labor productivity is defined as value added per hour worked. Input measures are on a per hour worked basis. Figures might not add up due to rounding.

Source: EU KLEMS database, March 2007 (http://www.euklems.net), described in Timmer *et al.* (2007).

the highest investor (the US) and a lowest investor (Italy) explains 1.2 percentage points out of a labor productivity difference of 3.0% during 1995–2004. The remaining 1.8 percentage point difference is almost entirely due to the differences in MFP growth between Italy and the US. Indeed cross-country differences in MFP growth seem to drive divergence in labor productivity growth. Although MFP growth is *on average* not an important contributor to growth, it has by far the largest variation in growth contributions, ranging from –1.2 percentage points in Spain, up to 1.3 percentage points in the US during the most recent period. In France, Germany and Italy, MFP growth is negligible or even negative. US growth rates of MFP are matched only in the Netherlands and Finland. Across all countries, the correlation between labor productivity and MFP growth rates is higher than 80% for both periods. This suggests that we need to focus on the determinants of MFP growth in trying to explain the recent variation in European labor productivity growth rates.

4. DETERMINANTS OF PRODUCTIVITY GROWTH

In the previous section we showed how investment in physical capital and human capital accounts for a substantial portion of labor productivity growth in market services in many countries. At the same time we found that cross-country differences in labor productivity growth are mainly due to differences in the efficiency with which the inputs are being used, as measured by MFP growth. To get further insight into the causes of MFP growth differences, we need to move beyond the growth accounting framework and explain differences in MFP growth. In this section we will use regression analysis to statistically gauge the importance of a number of potential determinants of MFP growth. For this purpose, we use a dynamic catching-up model that is commonly used in the literature.[14] Of the many determinants, we will focus here in particular on whether ICT use and the use of skilled labor generates externalities and whether regulatory barriers to entry hamper productivity growth.

4.1. The basic model of productivity growth

Following the dynamic catching-up model, MFP growth in an industry is determined by the strength of the domestic innovation process and the speed of imitation of best-practice technologies developed elsewhere.[15] The potential for technology transfer is captured by the technology gap relative to the global productivity leader. But the social and technological capabilities of an economy determine to what extent an industry innovates and exploits imitation opportunities. Aghion and Howitt (2006) argue that traditional European institutions were mostly suited for catching-up to the technology frontier and not so much for fostering innovation. For example, educational systems are more geared towards vocational schooling rather than higher education, capital markets are biased towards large incumbent firms rather than start-ups, labor market regulation promotes on-the-job training but hinders reallocations across firms and innovation systems, including patent protection laws and public R&D-institutes stimulate incremental innovation rather than major breakthroughs. To capture this idea, additional variables reflecting these institutional differences across countries are added to the model. Such variables might influence MFP growth

[14] See e.g. Cameron *et al.* (2005), Griffith *et al.* (2004), Nicoletti and Scarpetta (2003) and Vandenbussche *et al.* (2006).

[15] Innovation is defined as the development of technologies which are not only new to the country, but also new to the world.

by affecting the pace of innovation and the speed of technology imitation. For example, Griffith *et al.* (2004) find that spending on research and development (R&D) in manufacturing industries increases the pace of innovation but also speeds up technology imitation.

The basic model to be estimated is then:

$$\Delta \ln \text{MFP} = \beta(\text{Technology gap}) + \gamma X + \delta(X * \text{Technology gap}) \quad (1)$$

where X denotes one of several possible determinants of MFP of policy interest. The key parameters are β, which quantifies the importance of technology imitation that depends on the size of the technology gap, γ which shows the direct effect of X on productivity growth, and δ which gauges whether X has a larger effect on productivity growth for industries that are farther away from the frontier (positive sign) or closer to the frontier (negative sign). The regressions will also include dummies to control for fixed country-specific, industry-specific and time-specific factors.

In this section, we look at three possible determinants of MFP growth, namely the use of ICT capital, the use of university-educated workers and regulatory barriers to entry as all three have been suggested as important drivers of productivity growth.[16] The latter two play a prominent role in the recommendations of the Sapir Report (2004). Our focus on market services precludes us from examining some other explanatory variables which have been suggested, such as R&D and international trade, as their role is much more limited in services than in manufacturing industries.[17]

4.2. Technology gaps

To implement our empirical model, measures of technology gaps are a crucial ingredient. In this paper, we follow standard practice and measure technology gaps as MFP gaps even though MFP measures also reflect other factors besides technology (see Box 1). In the case of MFP gaps we need to measure the differences in output levels between countries that cannot be accounted for by differences in the use of inputs. The basic challenge of measuring MFP gaps is similar to that for measuring MFP growth. While the basic concept is fairly straightforward, the empirical implementation in the literature varies substantially, with most studies using crude productivity measures. In Table 7 we illustrate the difference between crude and sophisticated MFP level measures and show how better measurement can change the conclusions on technology leadership substantially. This will also have a major impact on the analysis of the determinants of MFP growth in the remainder of this section.

There are four main areas of concern when calculating MFP gaps, namely the measurement of output, relative prices, employment and capital, mirroring the

[16] See e.g. Brynjolfsson and Hitt (2003) on ICT, Vandenbussche *et al.* (2006) on university-educated workers and Nicoletti and Scarpetta (2003) on barriers to entry. For more details, see, respectively, Sections 4.3, 4.4 and 4.5.

[17] See e.g. Cameron *et al.* (2005) and Griffith *et al.* (2004) for the importance of those variables in manufacturing industries.

Table 7. Relative MFP measures, averaged across market services industries, 1997, US = 1

	(1)	(2)	(3)	(4)	(5)	(6)
	'Crude MFP'					'Sophisticated MFP'
Output measure	Value added	Value added	Value added	Value added	Value added	Gross output
PPP measure	GDP PPP	GDP PPP	GDP PPP	GO PPP	GO PPP	IO PPP
Employment measure	Persons	Hours	Hours by type	Hours by type	Hours by type	Hours by type
Capital measure	Stock	Stock	Stock	Stock	Services	Services
Austria	0.82	0.80	0.89	0.80	0.82	0.87
Belgium	0.82	0.95	1.01	1.01	1.05	1.09
Denmark	0.76	0.84	0.98	1.07	1.07	1.10
Finland	0.81	0.81	0.81	0.78	0.78	0.87
France	0.91	0.96	1.09	1.02	1.04	1.09
Germany	0.75	0.83	1.01	1.04	1.05	1.09
Italy	0.84	0.75	0.85	0.73	0.76	0.86
Netherlands	0.77	0.88	1.02	1.05	1.09	1.09
Spain	0.81	0.77	0.85	0.80	0.86	0.88
UK	0.79	0.80	0.98	0.93	0.94	0.97
US	1.00	1.00	1.00	1.00	1.00	1.00

Notes: Each column shows the MFP level relative to the United States in 1997, averaged over the nine market services. MFP levels in column (1) are calculated by subtracting the (cost-share weighted) relative levels of persons engaged and capital stocks, from the relative level of value added. All inputs and outputs are converted to a common currency using OECD GDP PPPs for 1997. For column (2), total hours worked by all persons is used as the measure for employment. For column (3), hours worked by university-educated and non-university-educated are distinguished and weighted using shares in labor composition. In column (4), industry-specific PPPs for industry gross output are used for converting value added and capital stocks to a common currency. In column (5), six different capital assets are converted to a common currency using capital services PPPs and weighted using shares in capital composition. In column (6), differences in relative prices for intermediate inputs are also taken into account and MFP levels are calculated by subtracting the (cost-share weighted) relative levels of hours worked by university- and non-university educated workers, capital services by six different capital assets and 45 types of intermediate inputs from the level of output. All conversions to a common currency are made using industry- and input-specific PPPs. See Inklaar and Timmer (2007b) for a more detailed description of the last measure.

discussion of productivity growth measurement.[18] First of all, most studies compare levels of value added, implicitly ignoring the role of intermediate inputs in the production process. Second, the output in different countries can only be compared once differences in relative prices are accounted for. This requires the use of purchasing power parities (PPPs). Many studies use GDP PPPs, since those are readily available, but these reflect relative prices of all goods and services in the economy. Here it is more appropriate to use PPPs that reflect the relative prices of output of that particular industry. Moreover, in this study we also take into account relative prices of the various inputs.

When it comes to measuring labor input, some studies only measure the relative number of persons engaged while others also account for differences in average hours worked across countries. It is preferable to measure differences in total hours worked by different types of workers as well, so as to account for differences in the composition of the workforce in different countries. Finally, most studies use a measure of the relative capital stock, but this does not adequately account for differences in the composition of capital input. Our detailed measure is based on a comparison of capital service levels, accounting for asset heterogeneity.

Table 7 shows the relative MFP level of each country, averaged across market services industries in 1997. The first column, which we label 'Crude MFP', uses the least sophisticated output, relative price and input measures. According to this productivity measure, the US is the most productive country in market services. However, once the necessary adjustments are made, five European countries show substantially higher levels than the US. This is because input levels in US market services are higher than indicated by the crude measures. Average hours worked in the US are generally much higher than in Europe, as indicated by the differences between columns 1 and 2. Similarly, skill levels in market services are higher in the US than in most European countries, biasing the crude MFP level (column 3). Another downward adjustment to US levels is made when moving from capital stocks to a measure including capital services, which adjusts for the higher share of ICT in the US as found in Table 3 (column 5). Looking at the final column, labelled 'Sophisticated MFP', the US no longer has the highest productivity level as about half of the European countries show higher MFP levels in 1997. The example of Germany is the most extreme: 'Crude MFP' shows Germany with the lowest productivity level and a gap of, on average, 25% compared to the US, while 'Sophisticated MFP' indicates that Germany is almost 10% more productive than the US on average. The rankings of MFP levels among European countries also shift considerably once more sophisticated output and input measures are introduced. The UK appeared to be leading Germany on the basis of the crude measure, but especially once corrections are made for longer hours worked and the relative high services output prices in the UK, Germany is leading the UK on MFP in market services by a wide margin in 1997. The adjustments can be even larger at a detailed industry level.[19]

[18] Inklaar and Timmer (2007b) provides a more detailed and rigorous discussion of these issues.

[19] Not shown, but available upon request from the authors.

As stressed before, Table 7 shows average levels across nine market services industries and technology levels differ substantially across industries. Table A3 (at the end of the Appendix) shows the technology leader in each of the nine market services industries, as well as the numbers two and three, in 1980, 1995 and 2004. Looking across all years, industries and countries, the average MFP level relative to the frontier is 69%, suggesting that there is substantial potential for imitation of frontier technologies. Given the problems in the measurement of services output volumes in some industries (see Appendix 1) these numbers need to be interpreted with care. Level comparisons are more sensitive to cross-country differences in measurement practices than growth rate comparisons.

4.3. The impact of ICT use on MFP growth

Once the technology gaps have been measured, we can begin testing the importance of our potential explanatory variables for cross-country differences in MFP growth. The first variable to be tested is ICT use. Since US labor productivity growth accelerated after 1995, much effort has gone into determining the importance of ICT use and the lack of acceleration in most other developed countries.[20] ICT, like other types of fixed capital, contributes to labor productivity growth by increasing the amount of capital input per hour worked. In Section 3 we showed that ICT use accounted for a major part of labor productivity growth, under the assumption that the benefits of ICT capital are reflected by the price paid for its use. A more contentious hypothesis is that ICT generates positive externalities, i.e. benefits that are higher than the costs being paid by the investor. Such externalities could be caused by, for example, network effects or complementary investments, such as organizational change, that go unmeasured.[21] The evidence on externalities from ICT use is mixed. There is some firm-level and industry-level research for the US that suggests super-normal returns to ICT, but a recent survey and meta-analysis concludes that the hypothesis of normal returns seems to hold (Stiroh, 2004).[22] The evidence for countries other than the US is more scattered and these national studies are generally not directly comparable.[23] Using the EU KLEMS database, we can focus on MFP and test for externalities of ICT use across a larger group of countries and industries. The externalities should show up as a positive correlation between ICT use and MFP growth as indicated in the model from Section 4.1.

[20] See e.g. Jorgenson and Stiroh (2000) and Timmer and van Ark (2005).

[21] See e.g. Stiroh (2002) and Basu, Fernald, Oulton and Srinivasan (2004).

[22] See e.g. Brynjolfsson and Hitt (2003) for a firm-level study and Stiroh (2002) and Basu, Fernald, Oulton and Srinivasan (2004) for industry-level studies.

[23] See OECD (2004) for a collection of national studies. Basu *et al.* (2004) and O'Mahony and Vecchi (2005) are among the very few cross-country studies of the productive impact of ICT and find super-normal returns to ICT-use in the US, but not in the UK. Some of our own comparative analysis focused on labor productivity growth, making it hard to identify externalities, or was of a more descriptive nature. See van Ark, Inklaar and McGuckin (2003) and Inklaar, O'Mahony and Timmer (2005).

Table 8 shows the results of this exercise. We first show a regression in which only the technology gap is used to explain MFP growth. The technology gap is defined as minus the log of the relative MFP level, so that a larger gap equals a lower relative level. Regardless of whether we use crude or sophisticated MFP growth and level measures, industries that are farther away from the technological frontier show faster MFP growth. In the light of the theoretical models discussed above, this might be interpreted as the result of international technology transfers, which benefit laggard countries more than countries close to the frontier. This finding of convergence of MFP levels within service industries confirms earlier analysis by, for example, Bernard and Jones (1996) and Nicoletti and Scarpetta (2003).

The results in Table 8 show that the evidence of the effects of ICT on MFP growth is mixed and depends on which measure of ICT adoption is used. The growth of ICT capital services is often used in the literature, but shows relatively little variation across industries since global price declines of ICT assets account for much of this growth.[24] Moreover, the right-hand side of Table 8 shows that using sophisticated MFP measures actually shows a negative relationship between ICT use and MFP growth. This would imply that the returns to ICT investments are lower than their costs. However, this evidence is relatively weak. When we use our preferred measure of ICT adoption, which is the share of ICT capital compensation in output, no such effect is found as shown in columns 9 and 10.[25] Similarly, there is also little evidence to suggest that ICT has a differential impact depending on the size of the technology gap as indicated by the insignificant interaction effects in Table 8. As a result, our cross-country analysis broadly confirms Stiroh's (2004) finding for the US that ICT assets are like other assets and earn their marginal product. This means that the contribution of ICT to labor productivity growth is well approximated by the growth accounting method applied in Section 3. ICT externalities do not explain the cross-country differences in MFP growth.

4.4. The impact of human capital on MFP growth

Skilled labor has also been suggested as another driver of technological change and an important source of productivity growth. Recently, Vandenbussche *et al.* (2006) presented a model where economies with a larger share of university-educated workers exhibit a faster rate of innovation, because skilled labor has a comparative advantage for innovation compared to imitation. Hence the growth-enhancing effect of skilled labor will be stronger for economies closer to the frontier as the opportunities for growth through imitation decrease. Vandenbussche *et al.* (2006) present cross-country

[24] See Inklaar and Timmer (2007a).

[25] In Appendix 4, we provide further robustness exercises. There we show that allowing for a longer time-horizon as in Brynjolfsson and Hitt (2003) and also advocated by O'Mahony and Vecchi (2005) does not change the results. We also show that the evidence for a negative relationship is found in only some industries and countries and that these negative coefficients are never found for both ICT use measures at the same time.

Table 8. The relationship between technology gaps, ICT use and productivity growth

Dependent variable: MFP growth	Crude MFP					Sophisticated MFP				
	1	2	3	4	5	6	7	8	9	10
Technology gap	0.027***	0.027***	0.019***	0.027***	0.021***	0.019***	0.019***	0.014**	0.020***	0.021***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
ICT use (growth of ICT)		−0.020	−0.050**				−0.024***	−0.038***		
		(0.015)	(0.023)				(0.009)	(0.012)		
ICT use (cost-share in ICT)				−0.042	−0.102				−0.053	−0.034
				(0.049)	(0.083)				(0.035)	(0.056)
Technology gap*ICT use			0.057**		0.120			0.038		−0.033
			(0.029)		(0.111)			(0.024)		(0.089)
Number of obervations	2376	2376	2376	2376	2376	2376	2376	2376	2376	2376

Notes: The table shows OLS regression estimates, explaining annual MFP growth by the technology gap relative to the frontier, measures of ICT use and the interaction between the technology gap and ICT use. *, ** and *** denote a coefficient significantly different from zero at, respectively, the 10%, 5% and 1% levels. Standard errors, consistent for heteroscedasticity and autocorrelation are in parentheses. For definitions of crude and sophisticated MFP, see Table 7. The industry-level data are a balanced panel for 9 market services industries in each of the 11 countries for the period 1980–2004 and all regressions include country, industry and year dummies. See Appendix 4 for robustness analysis.

evidence supporting this model and their study has subsequently been used in the Sapir Report (2004) to support the policy argument that higher education stimulates innovation. Their finding of skill externalities is all the more important because in an earlier study, Krueger and Lindahl (2001) conclude that while there is a high private return to education, the evidence for externalities at the level of industries or aggregate economies is far from conclusive.

However, the study by Vandenbussche *et al.* (2006) has two important drawbacks. First, growth differences between countries are only analyzed at the aggregate level, instead of across industries within countries, which leaves open the possibility that the positive correlation between human capital and MFP growth is due to a country-specific factor that is correlated with both human capital and growth.[26] The second drawback is that they rely on crude MFP measures that do not take into account differences in hours worked or in the educational attainment of the labor force. This means that their analysis cannot make a distinction between private and social returns to education. Only findings of social returns (or externalities) would provide a solid basis for policy initiatives.

In Table 9, we show that while the use of crude MFP measures provides a weak confirmation of the Vandenbussche *et al.* (2006) results, when using sophisticated MFP measures, the positive correlation between human capital and MFP growth is absent. In the left panel, we replicate the set-up by Vandenbussche *et al.* (2006), using aggregate economy data, no country fixed effects and crude MFP measures. Columns 1 and 2 show a significant positive effect of high-skilled workers on MFP growth. The interaction term also has a negative sign as predicted by the model of Vandenbussche *et al.* (2006), but is not significant. However, the positive effect of the share of high-skilled workers disappears once sophisticated MFP measures are used as shown in columns 3 and 4. In Appendix 4, we show that correcting the crude MFP measures for differences in hours worked and differences in the composition of the workforce causes the significant positive effect to vanish. In other words, Vandenbussche *et al.* (2006) are only estimating the private return to education, which is in part transferred to MFP growth due to measurement issues. In the right-hand panel, we redo the analysis for our set of nine market services industries. The industry-level estimates are consistent throughout and do not provide evidence that a larger share of high-skilled workers has an impact on MFP growth.[27] Our results for the use of skilled labor are therefore similar to those for ICT use: there is no evidence of productivity externalities from employing university-educated workers. As for ICT, this means that the contribution of a higher-educated workforce to labor productivity growth is well-captured in the growth accounting exercise from the previous section.

[26] See Temple (2000) for a more extensive discussion of the problem with cross-country growth regressions. This possibility is not entirely dispelled by the fact that the positive correlation between human capital and MFP growth disappears once taking into account country fixed effects.

[27] In Appendix 4 we show further robustness results, namely the results for all six MFP measures, results using different measures of the high-skilled share, including those from the same source as Vandenbussche *et al.* (2006), and different sets of dummies. None of this changes the main results reported in Table 9.

Table 9. The relationship between high-skilled workers and productivity growth at the aggregate and services industry level

Dependent variable: MFP growth	Total economy				Industry-level			
	Crude MFP		Sophisticated MFP		Crude MFP		Sophisticated MFP	
	1	2	3	4	5	6	7	8
Technology gap	0.027**	0.044**	0.015*	0.007	0.027***	0.021***	0.019***	0.020***
	(0.011)	(0.020)	(0.008)	(0.014)	(0.005)	(0.007)	(0.004)	(0.005)
High-skilled share	0.043**	0.065**	0.004	–0.009	–0.017	–0.034	–0.019	–0.017
	(0.020)	(0.027)	(0.016)	(0.034)	(0.035)	(0.038)	(0.023)	(0.023)
Technology gap*High-skilled share		–0.106		0.056		0.050		–0.006
		(0.126)		(0.121)		(0.038)		(0.034)
Number of observations	264	264	264	264	2376	2376	2376	2376

Notes: The table shows OLS regression estimates, explaining MFP growth by the technology gap relative to the frontier, the share of high-skilled (university-educated) workers in total hours worked and the interaction between the technology gap and the high-skilled share. *, ** and *** denote a coefficient significantly different from zero at, respectively, the 10%, 5% and 1% level. Standard errors, consistent for heteroscedasticity and autocorrelation are in parentheses. For definitions of crude and sophisticated MFP, see Table 7. The total economy data are a balanced panel for 11 countries, while the industry-level data are a balanced panel for 9 market services industries in each of the 11 countries, all of these for the period 1980–2004. The total economy results include year dummies and the industry-level results include country, industry and year dummies. See Appendix 4 for robustness analysis.

4.5. The impact of regulatory barriers to entry on MFP growth

Analyzing the effect of competition on productivity growth has taken great flight in recent years (see e.g. Aghion and Griffith, 2005 and Crafts, 2006 for overviews). The outcome of recent theoretical work is that more competition in product markets stimulates productivity growth because it stimulates innovation. Moreover, this effect might be stronger when an industry is closer to the technology frontier as those industries need to rely more on innovation compared to imitation.[28] Testing this prediction is not straightforward as competition in product markets cannot be observed directly. In some cases, changes in the regulatory regime can be used as a proxy for changes in competition. For example, Griffith, Harrison and Simpson (2006) use information on the implementation of the European Single Market Programme in different years and different countries and assuming a stronger effect in some manufacturing industries than others to establish that deregulation improved productivity growth in manufacturing by stimulating spending on R&D. Eventually, the liberalization of market services that is mandated in the EU Services Directive may provide a similar testing ground for the effects of regulation on productivity growth in market services.

In the meantime, the product market regulation measures compiled by the OECD are the most useful for the purpose of measuring the impact of regulation on productivity. Nicoletti and Scarpetta (2003) described the OECD Product Market Regulation Database measures in detail and provide the first systematic empirical analysis of the impact of regulation on productivity in a cross-country setting.[29] Their study has been highly influential and has been another source of inspiration for the Sapir Report (2004). Nicoletti and Scarpetta (2003) find some evidence that entry liberalization in services increases productivity growth, which supports the theoretical notion that entry barriers decrease the intensity of competition. Paradoxically, they find an impact of deregulation in services on productivity growth in manufacturing industries, but not in services industries.[30] In this section, we will further explore the link between deregulation and productivity growth by focusing on market services industries only, and zooming in on individual services industries for which long-run data on entry liberalization exist. One might expect that due to the heterogeneity in regulatory changes, evidence of an impact might only be found at a detailed industry level. With the EU KLEMS database such a detailed industry study is feasible.

We provide two analyses: one based on a regulation index averaged across all services industries, in the spirit of Nicoletti and Scarpetta (2003), and one based on industry-specific regulation indices. Table 10 shows that there is no effect of the average level of barriers to entry in services on MFP growth in market services

[28] See e.g. Acemoglu, Aghion and Zilibotti (2006) for such a model.

[29] Conway and Nicoletti (2006) present updates of their indicators for non-manufacturing industries.

[30] In Table 8, Nicoletti and Scarpetta (2003) report a significant impact of entry liberalization in services on productivity growth across all industries. However, in Table 7 they showed that this entry liberalization trend in services did not significantly affect productivity growth in services.

Table 10. The effect of barriers to entry on productivity growth in market services

Dependent variable: MFP growth	Crude MFP				Sophisticated MFP			
	1	2	3	4	5	6	7	8
Technology gap	0.027***	0.020**	0.016	0.050**	0.019***	0.009	0.009	0.010
	(0.005)	(0.009)	(0.010)	(0.021)	(0.004)	(0.007)	(0.006)	(0.012)
Barriers (average)	0.011	0.006			0.000	−0.004		
	(0.011)	(0.012)			(0.007)	(0.007)		
Barriers (industry-level)			−0.024**	−0.002			−0.010	−0.009
			(0.011)	(0.014)			(0.007)	(0.010)
Barriers*Technology gap		0.010		−0.052**		0.015		−0.002
		(0.012)		(0.022)		(0.009)		(0.017)
Number of observations	2376	2376	715	715	2376	2376	715	715

Notes: Dependent variable in the regressions is annual MFP growth in market services industries, independent variables are the technology gap of the industry relative to the productivity frontier and measures of barriers to entry from the OECD and their interaction. ** and *** denote a coefficient significantly different from zero at, respectively, the 5% and 1% level. Standard errors, consistent for heteroscedasticity and autocorrelation, are in parentheses. For definitions of crude and sophisticated MFP, see Table 7. Average barriers to entry uses an average index of barriers to entry, calculated by averaging across the entry barriers indices of all non-manufacturing industries for which the index is available for the 1980–2003 period, see Conway and Nicoletti (2006). Industry barriers to entry uses industry-specific entry barriers indices for retail (1996–2003), transport and storage (1980–2003, output-weighted average of road, rail and air transport), post and telecommunications (1980–2003 output-weighted average of post and telecommunications) and professional services (1996–2003).

industries. Moreover, this finding does not depend on the MFP measure that is used (columns 2 and 6).[31] There are also no significant interaction effects. This confirms the results of Nicoletti and Scarpetta (2003). One reason for this finding might be that entry liberalization occurred in different industries at different times, so using the trend averaged over industries may miss the relevant variation in the data. In the remaining columns of Table 10, we look at the effect of industry-specific barriers to entry on MFP growth. Unfortunately industry-specific data are more limited and only available for four industries, but the results seem more in line with theoretical predictions: all coefficients are negative, although only significant if crude MFP measures are used (column 3). The mixed nature of the results may be due to the fact that there is insufficient change over time in the barriers to entry in some industries. For example, in most countries, barriers to entry in retail trade hardly changed in the period for which data are available. To identify the effects of barriers to entry, an even more detailed focus on an industry with more variation in the regulatory measures might be needed.

Table 11 attempts this by looking at barriers to entry in two individual industries: transport and storage services and post and telecommunications services. For both industries, the OECD constructed a time series of barriers to entry covering our entire sample period from 1980 onwards and both industries experienced substantial entry liberalization in most countries.[32] This is most strongly so in post and telecommunications, which changed during the 1990s from a very restrictive to an almost fully liberalized industry environment in nearly all countries.[33] Table 11 shows that there is little effect of changes in barriers to entry in the transport industry, but in post and telecommunications, lower barriers are strongly related to higher MFP growth, even when sophisticated measures are being used (columns 7 and 8).[34] This finding provides support for the notion that lower barriers to entry promote productivity growth by increasing competition.

These results also raise the question of why we do not find such strong results for transport and storage. One possibility is that the change in barriers to entry for the post and telecommunications services was so strong that its effects became identifiable through the general noise in the data, while this was not the case in transport. An alternative explanation might be that the barriers to entry measure in transport is an average of a quite heterogeneous set of regulations, since it covers barriers to entry in rail, road and air transport. The summary OECD measures of regulation may not capture all the complexities of product market regulation and their interaction with

[31] Nor does it depend on the period covered, results are available on request. See also Appendix 4 for further tests using average trends as well as indirect measures of regulation as used by Conway *et al.* (2006).

[32] The OECD publishes indicators for road, rail and air transport and for postal services and telecommunications. We use output weights to construct weighted averages of these individual series.

[33] See Conway and Nicoletti (2006) on the trends and also Boylaud and Nicoletti (2000) on regulation and performance in telecommunications.

[34] Appendix 4 probes the robustness of this result by looking at different sets of dummies, different periods and alternative regulation indicators. These broadly confirm the main result in Table 11.

Table 11. The effect of barriers to entry on productivity growth in transport and communications

Dependent variable: MFP growth	Transport and storage				Post and telecommunications			
	Crude MFP		Sophisticated MFP		Crude MFP		Sophisticated MFP	
	1	2	3	4	5	6	7	8
Technology gap	0.203***	0.427***	0.115***	0.128***	0.075***	0.041	0.077***	0.068***
	(0.072)	(0.131)	(0.035)	(0.041)	(0.025)	(0.034)	(0.023)	(0.023)
Barriers	−0.022	0.056*	−0.012	−0.007	−0.056***	−0.130***	−0.041***	−0.060***
	(0.021)	(0.034)	(0.008)	(0.008)	(0.015)	(0.039)	(0.012)	(0.021)
Barriers*Technology gap		−0.334***		−0.011		0.091**		0.037
		(0.118)		(0.014)		(0.044)		(0.029)
Number of observations	264	264	264	264	264	264	264	264

Notes: Dependent variable is MFP growth in the transport industry or the telecommunications industry. All regressions include country and year dummies. For further notes, see Table 10.

labor market regulation and fine-grained industry-specific regulations such as, for example, land-zoning in retailing, accounting standards in business services or sanitation requirements in the hotel business.[35] Finally, it might be the case that regulatory barriers to entry in post and telecommunications represent a larger part of the overall entry barriers, which will also include fixed start-up costs, than in transport.[36] These possible explanations are not mutually exclusive, but in general point to the importance of detailed regulatory and productivity measures to analyse the impact of regulation on productivity.

5. CONCLUDING REMARKS

Over the past decade, much of Europe has missed out on productivity growth opportunities in market services. While growth surged in the US and some European countries, like Finland and the UK, most countries in Europe show slow and declining productivity growth in market services. Compared to the manufacturing sector, relatively little is known of the sources of labor productivity growth in market services. In this paper, we provide the most comprehensive evidence to date on the sources of growth by using the new EU KLEMS database. This database provides detailed information on outputs, inputs and productivity at the industry level for European countries and the US.

The first part of our analysis showed that investment in new technologies (ICT) and human capital have contributed substantially to growth across Europe and the US. Some European countries, like Denmark and the UK, show contributions from ICT use that are comparable to those in the US, while others, such as Italy and Spain, show much lower contributions. However, differences in investment rates of ICT and human capital cannot account for the cross-country differences in labor productivity growth in market services. Instead, the differences in the rate of efficiency gains, also referred to as multifactor productivity (MFP) growth, are as pronounced as the differences in labor productivity growth.

To arrive at these conclusions, we relied on a growth accounting methodology. This method assumes, amongst other things, that there are no productive externalities to the use of inputs. However, investors in ICT may for example benefit from network effects, while a large pool of skilled laborers might have a positive impact on the overall innovation process. We systematically analyze these possibilities but find no evidence in support of such externalities. This contradicts one of the key conclusions from the Sapir Report (2004). We show that the reason for this is that an analysis based on crude productivity data cannot distinguish between the private and social

[35] See Baily and Kirkegaard (2004) and Crafts (2006) on some of these considerations. Also see Kox and Lejour (2005) on the impact of differences in regulation across countries.

[36] See also the discussion in the Sapir Report (2004, p. 37), in particular on the distinction between fixed-line and mobile telephony.

returns to education. When this distinction is made, it appears that externalities cannot explain the differences in MFP growth. Since we do not find externalities to the use of ICT and university-educated workers, the case for government intervention in stimulating the diffusion of ICT or a preferential treatment of higher education vis-à-vis primary and secondary schooling is not supported by our analysis.

We also look at the impact of regulatory barriers to entry in services, since high barriers are likely to dampen the intensity of competition in the product market and hence, reduce the incentives for innovation. We find limited evidence in support of this hypothesis: MFP growth in post and telecommunications benefited substantially from entry liberalization during the 1990s. This supports the view that deregulation fosters productivity, but since we could not find similar evidence for other industries, the evidence suggests caution in the formulation of policy recommendations. For further insights, we need more detailed data on services regulation measures and a better understanding of how regulation affects competition in services. However, our analysis does not reject the notion that a decline in entry barriers in services may unlock the productivity growth potential of other market service industries provided that substantive action in this area is undertaken. Since various service industries have recently been liberalized within individual countries, cross-border liberalization, as envisaged in the EU Services Directive, is a natural way forward to gain productivity advantages in services across Europe.

A few cautionary notes are in order. First, while we find that, by and large, output measures of services tracks the 'true' performance of the sector reasonably well, there is substantial scope for improvement, especially for output measures for the financial and business services industry. Convergence towards best measurement practices and a higher degree of transparency by national statistical offices should help to inspire more confidence in the official statistics. Second, there is a large heterogeneity in productivity performance across market services and pooling these industries together in econometric analysis might not be warranted. Some of the market industries are as large as the total manufacturing sector and differ greatly in the degree of openness to international trade, foreign direct investment and intensity of formal R&D. Our findings of significant results from deregulations on MFP growth in post and telecommunications confirm that industry heterogeneity should be explicitly recognized in growth analysis.

Finally, when discussing multifactor productivity trends in services, it is important to take a broad view of 'technology'. While one might equate 'technology upgrading' with the introduction of new vintages of machinery, formal R&D and other hard science, in particular in manufacturing, the concept of technology as used in economic theory is actually much broader and therefore also applicable to services. 'Technology' describes the available knowledge about the various ways in which inputs, such as capital and labor, can be combined in the production of goods and services (Hulten, 2001). For service industries in particular, this may be more strongly related to changes in organizational structure, management and work practices than 'hard' technological changes. These types of technology might less easily spillover from one firm to another than manufacturing technologies, as they are embodied in company and management cultures. In fact, for a study of services a re-examination of the mechanisms through which technologies transfer from laggard to frontier countries seems needed. With the exception of recent work by, for example, Bloom and van Reenen (2006), measurement of the importance and transfer of intangible assets across countries, is still an underdeveloped field.[37] Integrating new measures and insights from both industry-level and micro-level research can be another important line of research that should provide further explanations for why productivity growth rates in market services have diverged across Europe and the US, as well as provide indications of the conditions under which Europe can exploit the growth potential of market services.

Discussion

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In this paper the authors provide the first detailed analysis of market services productivity across European countries and the US using the newly assembled EU KLEMS database. The database is now available for other researchers and the current paper will stimulate a rich vein of research. The paper is motivated by the difference in the aggregate performance of the US and European countries in labor productivity growth since 1995. It investigates the role that MFP growth – as opposed to factor accumulation – played in that difference and the possibility that externalities to ICT or human capital investment or differences in product market regulation can account for it. In my comment I will put into sharper focus a number of aspects of the data that emerge from their analysis. I begin by summarizing the case presented by the authors, point to some gaps in the case and highlight some of the issues associated with the new level estimates of MFP.

A way of bringing out the role of MFP performance in accounting for the differences in labor productivity growth between European countries and the US since 1995 is presented in Figure 2. This shows the decomposition in the productivity growth shortfall to the US in the 1995–2004 period into the four components of ICT and non-ICT capital deepening, the change in labor composition and MFP growth. I have ordered the countries in the figure according to the percentage contribution of MFP growth to explaining the *shortfall* to US labor productivity growth. Three countries illustrate the variation in experience. At the far right of the MFP columns, is the UK where more than the entire labor productivity growth deficit relative to the US in this

[37] See Black and Lynch (2005) for an overview of measuring organizational capital.

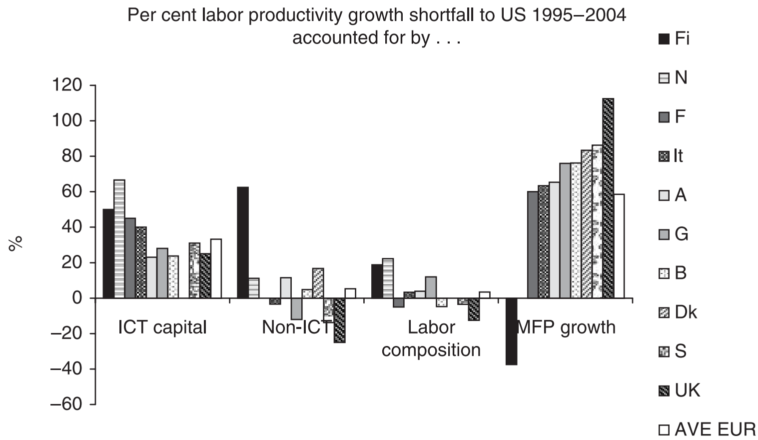

Figure 2. Decomposing the labor productivity growth shortfall to the US, 1995–2004

Source: Table 6 in this paper.

period is accounted for by weaker MFP growth: ICT investment was also weaker whilst non-ICT investment and labor composition changes were stronger than in the US. Interestingly as Table 6 in the paper shows, MFP growth in the UK slowed down slightly between 1980–1995 and 1995–2004 in contrast to its rapid acceleration in the US. At the opposite end of the spectrum is Finland where MFP growth in the post-1995 period was faster than in the US (shown by the negative bar) – whereas factor accumulation was weaker. The Netherlands is also interesting because its productivity growth shortfall is mainly accounted for by weaker ICT investment: MFP growth was at the same rate as in the US.

The core of the analysis in the paper is centred on the estimation of a dynamic catching up model where MFP growth is a function of a catch-up term (the β coefficient), the candidate growth factors, which are ICT, human capital and regulation, (the γ coefficients) and the interaction between the growth factors and the technology gap (the δ coefficients). The model is motivated by the hypothesis that there are potentially differential effects on productivity growth in industries that are close to the technology frontier as compared with their effects on industries far from it. For example, higher education is predicted to have a positive direct (frontier) effect but be less important for catching up, which would be captured by a negative interaction effect. Regulatory barriers are predicted to depress MFP growth at the frontier (negative γ) and to have a more detrimental effect for industries closer to the frontier (positive δ).

The predictions are tested using the disaggregated industry data for market services over the period from 1980 to 2004. Across a wide range of specifications, there is clear evidence of MFP convergence to the technology leader. However, there is no evidence that ICT investment or an increase in the proportion of university educated

Table 12. MFP leaders by market services industry: 1980 and 2004

	1980			2004		
	1st	2nd	3rd	1st	2nd	3rd
Motor trade	Belgium	Denmark	UK	Belgium	Netherlands	Finland
Wholesale	Belgium	Germany	UK	Germany	Netherlands	Finland
Retail	Denmark	Belgium	Germany	Denmark	Germany	France
Hotels & Rest.	France	Germany	Denmark	Austria	Germany	US
Transport	Netherlands	UK	US	Netherlands	US	France
Post & Telecomm.	UK	US	Belgium	France	Germany	UK
Fin. Intermediation	Italy	UK	US	Italy	Belgium	Denmark
Bus. Services	UK	US	Spain	US	Belgium	Denmark
Social & personal	Netherlands	Austria	Denmark	France	Netherlands	Germany

Source: Table A3, at the end of the Appendix.

workers has a direct effect on the rate of technological progress (the frontier effect) or that its effects depend on the technology gap. The results on human capital stand in contrast to those for the aggregate economy reported by Vandenbussche *et al.* (2006). Inklaar *et al.* demonstrate that the source of the difference between their results and those of Vandenbussche *et al.* lies with their corrections to the MFP measures – in particular their corrections in the measured labor inputs for changes in hours worked and in skill composition. Their claim is that once inputs are measured correctly, there is no additional impact of either ICT or higher education on MFP growth. This finding is of considerable policy relevance since if it is valid, the heavy emphasis in recent European debates on the likely innovation benefits from government policies to promote higher levels of investment in ICT and higher education would be misplaced – at least in so far as it applies to market services.

The authors find a little more support for the argument that regulatory barriers affect MFP – but only in one industry, post and telecommunications. However, they do not find any support for the presence of an interaction effect whereby lowering barriers has a greater effect in boosting productivity growth in industries closer to the frontier.

In view of the considerable investment in data collection and in the creation of sophisticated measures of MFP and given that the initial results using these measures do not provide clear support for policies that are being promoted in Europe, it is important to think carefully about the construction of the MFP measures and to look at what the measures reveal. The most striking finding is that contrary to the impression given by the paper's motivation, the author's calculations show that the US is not the technology leader as measured by 'sophisticated' MFP in market services. In 1980, the US was the MFP leader in none of the nine market services industries and ranked second in two. By 2004, the US led in one industry and was second in one. Table 12 lists the first three countries in each of the market services industries according to the

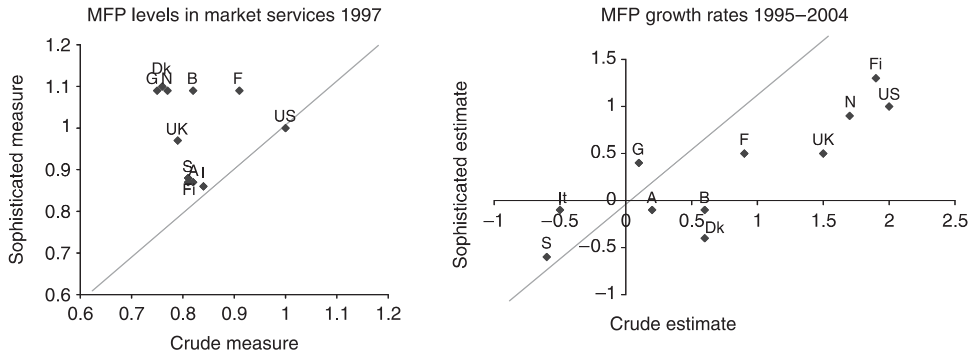

Figure 3. The effect of more sophisticated measurement of MFP on country rankings in levels and growth rates.

Source: Table 7 in the paper and Table A2 in the Appendix.

authors' preferred measure of MFP. There are several surprising aspects of the data: first is the limited presence of the US as technology leader either at the beginning or the end of the period, second is the apparently remarkably good performance of the UK in 1980 just as the Thatcher reforms were being launched, and third is the premier position of Italy as productivity leader in financial services.[38]

The analysis in the paper reveals that the world looks quite different when viewed through the lens of the more sophisticated measures of productivity. The corrections make a substantial difference both to the cross-country levels and to growth rates. Figure 3 shows that although the US is the leader in a bench-mark year (1997) when the crude measure of MFP is used, five European countries have higher MFP after the various adjustments have been made. This difference is due mainly to correcting for the quality of labor input (US inputs are higher than are captured by 'persons') and to implementing double deflation using industry level PPPs. In the right hand panel of Figure 2, which shows the data for the post-1995 period, it is clear that in moving from the crude to the sophisticated measure of MFP, relative growth rates are also affected. There are big downwards adjustments for the US, UK and Denmark and upward adjustments for Germany and Italy. The substantial productivity growth advantage of the UK over Germany virtually disappears when the more sophisticated measure is used.

To sum up, the paper by Inklaar *et al.* produces results about the determinants of productivity growth in market services that are somewhat at odds with prevailing views in the European debate – in particular, they do not find that ICT or higher education are important for MFP growth either directly or differentially for industries close to or further from the technology frontier. They find some support for the role

[38] The most recent OECD Economic Survey of Italy (2007) provides a summary of evidence of inefficiency relative to other OECD countries in the Italian financial services industry (pp. 74–75).

of regulatory barriers in the post and telecommunications industry but not more generally. As I have illustrated, the sophisticated measures of MFP levels and growth rates that they derive are also somewhat puzzling: in contrast to the motivation of the paper and much of the debate in Europe, the data reveal that it is not European countries but the US that is lagging in productivity levels in most industries throughout the period. Although the authors point out that the problems with cross country comparability in measurement are greater for levels than for growth rates, nevertheless the levels play a key role in the econometric analysis (via the catch-up term). Taken at face value, these productivity indicators suggest that if Europe is already ahead in MFP in most market services industries, its problem needs to be reformulated.

Alternatively, the results may indicate that further thought is needed in checking that the sophisticated MFP measure accounts for all relevant factors. Two possible confounding factors come to mind. The first relates to the assumption of competitive factor and product markets – the example of the top ranking of the Italian financial intermediation industry is suggestive that rents may be being captured in the MFP measure. Second, the measure of human capital that is used may be too narrow, with the result that some of it is included by default in measured MFP. Inklaar *et al.* use the share of university graduates in labor input as the high skill measure. If this omits a substantial proportion of vocationally qualified high-skill workers in some countries, it may lead to an overestimate of MFP levels in such countries. The authors are aware of this potential problem but point out that the data to deal with it are not generally available. To indicate that the problem exists we focus on four countries for which much more detailed comparable human capital data are available (US, UK, France and Germany). We can then compare the ranking of the level of high-skill human capital that Inklaar *et al.* use with the ranking based on the richer classification (Mason *et al.* 2007; cited by Inklaar *et al.*). Whereas Germany ranks fourth and France third of these four countries in Inklaar *et al.*'s measure of the human capital content of market services, Germany ranks first in each market services industry and France second in more than half of them in Mason *et al.*

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This paper uses a new dataset, created as part of the EU KLEMS project, to analyze productivity in Europe, and especially the productivity of market services. The main aims of the empirical analysis are (1) to describe and compare productivity levels and growth rates in market services in the US and 11 European economies; (2) to examine the role of information and communication technologies in service sector productivity growth; and (3) to explain the differences between the EU, where growth in the service sector has often been slow, and the US, where it has often been fast.

The construction of the dataset is a major and valuable contribution in itself, and one that will enable some important research questions to be addressed. The current paper already shows how to make constructive and informative use of the new data. In discussing the paper's empirical analysis, there are two sets of points I would like to make: one set narrowly statistical, and the other more general.

The statistical points relate to the use of convergence ideas in the empirical models. Some of the models estimated in the paper, such as those in Table 8, relate growth in multifactor productivity (MFP) to the extent of international technology gaps. In the paper's models, these gaps are defined as minus the log of the relative MFP level, so that a larger gap corresponds to a lower relative MFP level. The paper estimates the relationship between growth and technology gaps using pooled regressions, based on data on 11 countries and 9 market services sectors. The empirical findings are modified slightly when the authors use their new series for relative MFP, rather than cruder ones.

In estimating a relationship between growth and initial conditions, this exercise bears a family resemblance to the conditional convergence regressions used in the literature on aggregate economic growth. As elsewhere in the sector-level work on productivity, there is probably more to be learnt from the cross-country growth literature than first meets the eye. First, given that the implied rates of convergence are relatively low, one issue is whether tests of this kind can distinguish genuine convergence from cases where relative MFP is not mean-reverting. Second, it would be interesting to consider the possible implications of measurement error for the estimates. This is especially so, given that a major contribution of this paper is the construction of new and more sophisticated MFP series, which should be more accurate than those previously available.

To see why this is relevant, it is worth considering the relationship between measurement error and convergence. Investigations of convergence are essentially asking whether today's outcomes are strongly or weakly related to past outcomes. A weak association corresponds to a faster rate of convergence. Put differently, if units like countries or sectors are converging to steady-states quickly, this means that the influence of the initial conditions must be dissipating quickly. It is then easy to see what can happen under measurement error. Since the errors in the data will weaken the association between today's outcomes and past outcomes, they will tend to bias the results towards faster convergence. This effect has been discussed in De Long (1988) and Temple (1998).

If we look at the results in Table 8, the move from the basic MFP series to the more sophisticated series lowers the estimated rates of convergence. This pattern is appealing, because it is the one we should expect, if the MFP data constructed by the authors genuinely contain less (classical) measurement error than the more basic data. There would be several ways of exploring this further. In principle, it would be possible to use instrumental variables, method-of-moments corrections, or carry out reverse regressions, as in Temple (1998). Until the literature on sector-level productivity acknowledges the possibility of measurement error in more detail, some of its findings on convergence should be treated with caution.

The second point I want to make is about the underlying economics. The empirical analysis in the paper points towards an interesting research question, which is why differences in services MFP across countries might persist. Perhaps part of the explanation lies in productivity differences across firms within a given country. Many services involve significant scope for quality differences, and output that is non-standardized: think of architects, for example. These characteristics have implications not only for measurement, but also for market structure, because they could allow firms of widely-varying productivity to co-exist even in equilibrium. It could be argued that the service sector has exactly the combination of sunk costs (through reputation-building) and *ex ante* uncertainty about productivity that leads to equilibrium productivity differentials in Hopenhayn (1992) and Melitz (2003).

This suggests, for future research, an interesting explanation for international differences in service sector productivity. Differences across countries may be strongly influenced by the extent to which productivity varies within each country: for example, those countries with a long tail of weak performers will have lower average productivity. In turn, this perspective could shed new light on product market regulation and competition policy. There might be scope for investigating these questions with KLEMS data, or perhaps more obviously, with data at a more disaggregated level.

These ideas hint at the way that better data can invite deeper research questions and provide a firmer basis for policy analysis. Whether or not these specific ideas can be easily pursued, the authors deserve great credit for putting together such a useful dataset, and for analyzing it to such good effect.

Panel discussion

Philippe Aghion remarked that the paper's results are hard to reconcile with recent contributions finding that ICT or human capital or institutional structures account for cross-country differences in productivity. While the literature hotly debates which of these factors may be more relevant, this paper finds that none of the standard factors accounts for productivity differences, and this is puzzling. Peter Schott pointed out that comparisons of labor input quality across countries are very imprecise, and wondered whether firm-level data may be more informative in the relevant respects. Stephen Redding suggested that firm-level data might indeed be useful for the purpose of assessing the relationship between export activity and productivity, and that data on multinational firms could help disentangle firm and country effects. Anne Sibert pointed out that since the role of ICT is more important when reorganization is easier, interactions between ICT and possibly different measures of regulation (such as land-use restrictions in the case of retail trade) should play a key role.

Francesco Caselli found it very striking that, according to the paper's results, so many countries appear to have experienced many years of negative productivity growth. He wondered whether composition effects may spuriously produce such evidence as countries reallocate factors between different value-added sectors within services industries, or perhaps negative measured productivity growth could be due to adjustment or adoption costs. Christian Schultz noted that the tightness of labor markets might influence such aspects. Werner Sinn added that public employment could also be relevant: in the public sector, production is essentially measured on the basis of wages, which may not be appropriate for the purpose of assessing welfare-relevant productivity developments. Daria Taglioni thought that the output of services sectors is indeed generally difficult to measure, even in the private sector, and that the implications of measurement difficulties for the paper's results could be assessed considering their different relevance for different manufacturing sectors, many of which have a large services component.

APPENDIX 1. OUTPUT MEASUREMENT IN MARKET SERVICES

Market services productivity trends are much less studied than trends in manufacturing. A major reason for this is the concern about the availability of adequate measures of services output and productivity, often referred to the overviews of measurement issues by Griliches (1992, 1994). It is well-known that the problem of measuring output is in general much more challenging in services than in goods-producing industries. Indeed, Griliches (1994) classified a large part of the services sector as 'unmeasurable'.[39] Most measurement problems boil down to the fact that service activities are intangible, more heterogeneous than goods and often dependent on the actions of the consumer as well as the producer. While the measurement of nominal output in market services is generally less problematic, being mostly a matter of accurately registering total revenue, the main bottleneck is the measurement of output volumes, which requires accurate price measurement adjusted for changes in the quality of services output.[40]

There is no doubt that problems in measuring services output still exist, but many statistical offices have made great strides forward in the measurement of the nominal value and prices of services output.[41] Still, progress has been uneven, both across industries and countries.[42]

To provide an assessment of statistical practices in European countries, we have made use of a series of recent surveys of volume measurement practices by national

[39] See also Sichel (1997) for the likely impact of these 'unmeasurable' industries and Wölfl (2003) for an extensive general overview of measurement issues in services.

[40] A prominent exception to measurement problems for nominal output is for banking, see Wang, Basu and Fernald (2004).

[41] See, for example developments in the US Bureau of Labor Statistics (BLS) (Horrigan, Bathgate and Swick, 2006). Triplett and Bosworth (2004) discuss the long-term improvements made in the US statistical system on measuring services. The Voorburg Group on Service Statistics, which was set up in 1986, has brought together statisticians from national statistical institutes around the world, including Europe, to review and improve methods concerning the measurement of services (see http://www4.statcan.ca/english/voorburg/2004-background.htm).

[42] In a study of measurement practices in the UK, Crespi *et al.* (2006) argue that measurement problems in the UK are most severe in finance and business services.

statistical institutes (NSI's) in the European Union. These inventories were mandated by Eurostat. Using the Eurostat (2001) *Handbook on Price and Volume Measures in National Accounts*, NSI's have graded their volume measurement techniques in each industry as an A, B or C-method. An A-method is considered as most appropriate, a B-method as an acceptable alternative to an A-method, and a C-method as a method that is too biased to be acceptable, or one that is conceptually wrong. For example, for business and management consultancy services, an A-method would be the collection of actual or model contract prices and such prices need to account for changes in the characteristics of the contracts over time. A typical B-method could be the use of charge-out rates or hourly fees for business services or the price index of a closely-related activity, such as accounting or legal services. A C-method would be any other deflation method, such as using the overall CPI or PPI (Eurostat, 2001, pp. 107–108).

The inventories by the NSI's referred to above describe the state of measurement practices in each country around the year 2000. Most countries gave explicit grades for each industry and where possible, we cross-checked this grading with the description in the Handbook.[43] Table A1 shows the share of output in each industry that is deflated using A, B and C-methods, averaged across those European countries in our dataset for which these inventories were available. The table shows that measurement practices in market services are far from perfect since A-methods, with the exception of hotels and restaurants, account for only a small share of output in most industries. It also shows that measurement is most problematic in finance and business services,

Table A1. Average share of value added in market services in European countries deflated using A, B or C-methods around the year 2000 (%)

ISIC rev3 code	Industry	*A*	*B*	*C*
50	Motor trade	0	78	22
51	Wholesale trade	0	78	22
52	Retail trade	0	78	22
55	Hotels and restaurants	73	20	8
60–63	Transport and storage	9	70	21
64	Post and telecommunications	1	86	13
65–67	Financial intermediation	0	54	46
71–74	Business services	6	47	46
90–93	Social and personal services	16	47	37
	Average	12	62	26

Notes: Classification into A, B and C-methods are by national statistical offices, based on Eurostat (2001). A-method is defined as most appropriate, B-method as acceptable and C-method as unacceptable. Average share is calculated based on information for Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands and the UK. For each country and each industry we use information on the share of value added deflated using A, B or C-methods, and for each industry (as well as the total average) these shares are averaged across countries.

[43] In a number of cases, the grades were adjusted to better conform to the Handbook. For some countries, coding was missing and had to be done based on the given description of measurement practice.

where nearly half of output is deflated with C-methods. As might be expected, there is also substantial variation in measurement across countries, but generally hotels and restaurants are best measured and finance and business services are worst measured. However, it also becomes clear that the scope of measurement problems should not be overstated: on average about a quarter of output is deflated using inappropriate (and thus potentially misleading) deflators while for the remainder, at least acceptable methods are used. For example, Inklaar and Timmer (2007c) provide an analysis of how B-method deflation in retail trade compares to a conceptually superior alternative (A-method). They conclude that while more appropriate deflation leads to somewhat different growth rates of output and productivity, the broad pattern of growth differences across countries (which is what matters for this study) is not strongly affected.

A few notes of caution are in order here. First, the inventories of measurement practices reflected the situation around the year 2000 and it is not known to what extent new practices are carried through in revisions of historical time series published by the statistical offices. Second, while the best measured and worst measured service industries are the same across countries, there is still substantial variation. For example, in one (small) European country the share of C-methods is 77%, while in another country, this share is only 5% compared to an average share of C-methods of 26%. This suggests that convergence to best measurement practice within Europe would already allow for a more accurate assessment of productivity growth in market services. This would not so much require additional conceptual work, but more effective adoption of best practices among NSI's (see also Crespi *et al.*, 2006). In general, researchers and other users would benefit substantially from more openness and transparency by NSI's about measurement practices. The unpublished, confidential and infrequent measurement inventories in Europe stand in sharp contrast to easily accessible publications as published in the *Survey of Current Business* of the US Bureau of Economic Analysis, which regularly reports on updates in the methodologies used in constructing the US National Accounts.

APPENDIX 2. DATA SOURCES AND METHODOLOGY

Growth accounting set-up

To assess the contribution of the various inputs to aggregate economic growth, we apply the growth accounting framework as developed by Jorgenson and associates (see, for example, Jorgenson, Ho and Stiroh, 2005). It is based on production possibility frontiers where industry gross output is a function of capital, labor, intermediate inputs and technology, which is indexed by time, T. Each industry, indexed by j, can produce a set of products and purchases a number of distinct intermediate inputs, capital service inputs, and labor inputs to produce its output. The production functions are assumed to be separable in these inputs, so that:

$$Y_j = f_j(K_j, L_j, X_j, T) \tag{A1}$$

where Y is output, K is an index of capital service flow, L is an index of labor service flows and X is an index of intermediate inputs, either purchased from domestic industries or imported. Under the assumptions of competitive factor markets, full input utilization and constant returns to scale, the growth of output can be expressed as the (cost share) weighted growth of inputs and multifactor productivity (denoted by A^Y):

$$\Delta \ln Y_{jt} = \bar{v}_{jt}^X \Delta \ln X_{jt} + \bar{v}_{jt}^K \Delta \ln K_{jt} + \bar{v}_{jt}^L \Delta \ln L_{jt} + \Delta \ln A_{jt}^Y \tag{A2}$$

where $\bar{v}^i$ denotes the two-period average share of input i in nominal output and $\bar{v}^L + \bar{v}^K + \bar{v}^X = 1$. Each element on the right-hand side indicates the proportion of output growth accounted for by growth in intermediate inputs, capital services, labor services and MFP, respectively. By dividing through total hours worked and rearranging, the breakdown of value added per hour growth can be made as follows:

$$\Delta \ln \frac{VA_{jt}}{H_{jt}} = \bar{w}_{jt}^K \Delta \ln \frac{K_{jt}}{H_{jt}} + \bar{w}_{jt}^L \Delta \ln \frac{L_{jt}}{H_{jt}} + \Delta \ln A_{jt}^{VA} \tag{A3}$$

where $\bar{w}^i$ denotes the two-period average share of input i in nominal value added. This formulation allows us to assess the contribution of capital deepening (capital services per hour worked) and labor composition change (labor services per hour worked) to labor productivity growth.

Growth accounting decompositions are made on the basis of certain restrictive assumptions such as cost-minimizing producers and competitive factor and product markets. These are unlikely to be fully satisfied in practice, but growth accounting provides a straightforward, non-parametric and consistent method which can be used as a starting point to identify the contributions of inputs and productivity to growth. It can also serve as a benchmark as most economy policy frameworks are nowadays focused on creating an economic environment that more or less satisfies the free-market conditions. In Section 4 we found no evidence that the growth accounting assumptions on the returns to skills and ICT capital had to be rejected.

Data sources

The data for this paper are taken from the first version of the EU KLEMS database (March 2007). This database is publicly available at www.euklems.net. This is a new database which provides measures of economic growth, productivity, employment creation, capital formation and technological change at a detailed industry level for European Union member states, Japan and the US from 1970 onwards. It has been put together by a consortium of sixteen research institutes across Europe in close cooperation with National Statistical Offices and is financed by the European Commission. The database is specifically designed to provide all data necessary for growth and level accounting exercises as described in the main text.

The EU KLEMS database provides long time-series going back to 1970 through linking of national account data series from different vintages in a harmonized and consistent way. National Account series are further subdivided into the necessary industry, labor and capital detail on the basis of additional secondary data sources. For example, industry detail in output and employment series is increased by additional information from industry surveys. To have a breakdown of various labor categories, use is made of additional surveys, such as Labor Force Surveys, which are available on an annual basis for most countries. For a breakdown of investment into various asset types, additional information from input–output tables and investment surveys was used. Especially series on investment in computers and communication equipment are normally not provided in the National Accounts. Further detail on the sources and methods used for each country can be found in Timmer *et al.* (2007a).

The database has a number of unique characteristics compared to other existing multi-country industry-level databases such as the OECD STAN database. Specifically, the EU KLEMS database contains measures of gross output, intermediate inputs, labor service input and capital services input at the level of 30 industries (of which 9 are market service industries). Hours worked are cross classified by age (3 types), gender (2 types) and educational attainment (3 types). Labor services input is measured by weighting hours worked by each of the eighteen types of labor in a Törnqvist aggregation procedure, where weights are given by the share of each type in total labor compensation. Thus, the changes in the composition of the labor force are taken into account which is important as in most countries, the share of more productive higher-skilled workers is increasing, albeit at different speeds. Similarly, changes in the composition of the capital stock are taken into account by distinguishing six asset types at the industry level (see below for the measurement of capital stocks and services). This is the first time that labor and capital services measures are available at an industry-level for a wide range of countries.

Importantly, output and input measures in EU KLEMS are harmonized across countries in various ways. This includes harmonization of industrial classifications and harmonization of classifications for labor types and capital assets. But also the measurement of capital stocks was harmonized by using similar assumptions concerning the depreciation model (which is a perpetual inventory model with geometric depreciation rates) and depreciation rates (which vary by asset type and industry but not by country).[44] As investment prices of IT-hardware are not quality-adjusted in all countries, we use the harmonization procedure introduced by Schreyer (2002) to adjust for differences in deflation measures (see Box 2 in main text).

[44] Although depreciation rates most likely vary across countries due to differences in the pace of structural change, there is no empirical evidence available which can be used to model this. Assuming identical rates across countries is a second-best solution. The rates are based on the rates used by the BEA in the US national accounts (Fraumeni, 1997).

Growth of capital services

According to the perpetual inventory model (PIM), the capital stock (S) is defined as a weighted sum of past investments with weights given by the relative efficiencies of capital goods at different ages:

$$S_{i,T} = \sum_{t=0}^{\infty} \partial_{i,t} I_{i,T-t} \tag{A4}$$

with $S_{i,T}$ the capital stock (for a particular asset type i) at time T, $\partial_{i,t}$ the efficiency of a capital good i of age t relative to the efficiency of a new capital good, and $I_{i,T-1}$ the investments in period $T-t$.[45] As in the work of Jorgenson *et al.*, a geometric depreciation pattern is applied (Fraumeni, 1997). With a given constant rate of depreciation δ_i different for each asset type, we get $\partial_{i,t} = (1-\delta_i)^{t-1}$, so that:

$$S_{i,T} = \sum_{t=0}^{\infty} (1-\delta_i)^{t-1} I_{i,T-t} = S_{i,T-1}(1-\delta_i) + I_{i,T} \tag{A5}$$

If one assumes that the flow of capital services from each asset type i (K_i) is proportional to the average of the stock available at the end of the current and the prior period ($S_{i,T}$ and $S_{i,T-1}$), one can aggregate capital service flows from these asset types as a translog quantity index to:

$$\Delta \ln K = \ln K_T - \ln K_{T-1} = \sum_i \bar{v}_i [\ln S_{i,T} - \ln S_{i,T-1}] \tag{A6}$$

where weights are given by the average shares of each component in the value of capital compensation $\bar{v}_i = \frac{1}{2}[v_{i,T} + v_{i,T-1}]$ and $v_{i,T} = p_{i,T} S_{i,T} \Big/ \sum_i p_{i,T} S_{i,T}$.

The estimation of the compensation share of each asset, v_i, is related to the user cost of each asset. The user cost approach is crucial in any analysis of the contribution of ICT capital to growth, because the annual amount of capital services delivered per euro of investment in ICT is much higher than that of an euro invested in, say, buildings. While an ICT asset may typically be scrapped after five years, buildings may provide services for decades. ICT assets have a high user cost due to high depreciation and declining prices. For example, the user cost of IT-machinery is typically 50 to 60% of the investment price, while that of buildings is less than 10%. Therefore one euro of IT capital stock gets a heavier weight in the growth decomposition than one euro of building stock. This different weight on capital services is picked up by using the rental price of capital services, $p^K_{k,t}$, which reflects the price at which the investor is indifferent between buying or renting the capital good for a one-year lease in the rental market. In the absence of taxation the equilibrium condition can be rearranged, yielding the familiar cost-of-capital equation:

[45] An important implicit assumption made here is that the services by assets of different vintages are perfect substitutes for each other.

$$p^K_{k,t} = p^I_{k,t-1} r_t + \delta_k p^I_{k,t} - [p^I_{k,t} - p^I_{k,t-1}] \tag{A7}$$

with r_T representing the nominal rate of return, δ_k the depreciation rate of asset type k, and $\dot{p}^I_{k,T}$, the rate of inflation in the price of asset type k.[46] This formula shows that the rental fee is determined by the nominal rate of return, the rate of economic depreciation and the asset specific capital gains.

The nominal rate of return is determined *ex post* (endogenous approach). It is assumed that the total value of capital services for each industry equals its compensation for all assets. This procedure yields an internal rate of return that exhausts capital income and is consistent with constant returns to scale. This nominal rate of return is the same for all assets in an industry, but is allowed to vary across industries, and derived as a residual as follows:

$$r_{j,t} = \frac{p^K_{j,t} K_{j,t} + \sum_k [p^I_{k,j,t} - p^I_{k,j,t-1}] S_{k,j,t} - \sum_k p^I_{k,j,t} \delta_k S_{k,j,t}}{\sum_k p^I_{k,j,t-1} S_{k,j,t}} \tag{A8}$$

where the first term $p^K_{j,t} K_{j,t}$ is the capital compensation in industry j, which under constant returns to scale can be derived as value added minus the compensation of labor.

Growth of labor services

As for capital, the productivity of various types of labor, such as low- versus high-skilled labor, will differ across these types. Standard measures of labor input, such as number of persons employed or hours worked, will not account for such differences. Hence it is important that measures of labor input take account of the heterogeneity of the labor force in measuring productivity and the contribution of labor to output growth. In the growth accounting approach, these measures are called labor services, as they allow for differences in the amount of services delivered per unit of labor. It is assumed that the flow of labor services for each labor type is proportional to hours worked, and workers are paid their marginal productivities. Then the corresponding index of labor services input L is given by

$$\Delta \ln L_t = \sum_l \bar{v}_{l,t} \Delta \ln H_{l,t} \tag{A9}$$

where $\Delta \ln H_{l,t}$ indicates the growth of hours worked by labor type l and weights are given by the period average shares of each type in the value of labor compensation. In this way, aggregation takes into account the changing composition of the labor force. We cross-classify labor input by educational attainment, gender and age (to

[46] The logic for using the rental price is as follows. In equilibrium, an investor is indifferent between two alternatives: earning a nominal rate of return r on an investment q, or buying a unit of capital collecting a rental p and then selling it at the depreciated asset price $(1 - \delta)q$ in the next period. Assuming no taxation the equilibrium condition is: $(1 + r_T)q_{i,T-1} = P_{i,T} + (1 - \delta_i)q_{i,T}$, with P as the rental fee and q_i the acquisition price of investment good i (Jorgenson and Stiroh, 2000, p. 192). Rearranging yields a variation of the familiar cost-of-capital equation: $P_{i,T} = q_{i,T-1}r_T + \delta_i q_{i,T-1} - [q_{i,T} - q_{i,T-1}]$, which when dividing the rental fee by the acquisition price of the previous period transforms into equation (A4).

proxy for work experience) into 18 labor categories (respectively $3 * 2 * 3$ types). Typically, a shift in the share of hours worked by low-skilled workers to medium- or high-skilled workers will lead to a growth of labor services which is bigger than the growth in total hours worked. We refer to this difference as the labor composition effect.[47]

Series on hours worked by labor types are not part of the core set of national accounts statistics put out by NSIs, not even at the aggregate level. Also, there is no comprehensive international database on skills which can be used for this purpose. Previous cross-country studies relied on rough proxies of skills such as distinguishing production versus non-production workers as in Griffith, Redding and van Reenen (2004) or combined a wide variety of disconnected sources such as in Nicoletti and Scarpetta (2003). More in-depth country studies such as Koeniger and Leonardi (2007) use consistent data for wages and employment by skill from one particular source. This is also the strategy followed in EU KLEMS. For each country covered, a choice was made for the best statistical source for consistent wage and employment data at the industry level. In most cases this was the labor force survey (LFS), which in some cases was combined with a earnings survey when wages were not included in the LFS. In other instances, an establishment survey, or social-security database was used.[48] Care has been taken to arrive at series which are consistent over time. This involved significant additional effort, as most employment surveys are not designed to track developments over time, and breaks in methodology or coverage frequently occur.

Level accounting set-up

Comparing productivity levels across countries is in many ways analogous to comparisons over time. However, while one typically compares productivity in one year with productivity in the previous year, there is no such natural ordering of countries. Therefore the comparison should not depend on the country that is chosen as the base country. There are various index number methods that can be used to make multilateral comparisons. We use the method suggested by Caves, Christensen and Diewert (1982). This index mirrors the Törnqvist index approach used in our growth accounting, but all countries are compared to an artificial 'average' country (*AC*). This average country is defined as the simple average of all *N* countries in the set. For example, a multilateral index of capital service input in country *c* is given by:

$$\ln \frac{K_c}{K_{AC}} = \sum_j \bar{v}_j \ln \frac{S_{j,c}}{S_{j,AC}} \qquad \text{(A10)}$$

[47] This difference is also known as 'labor quality' in the growth accounting literature (see e.g. Jorgenson, Ho and Stiroh 2005). However, this terminology has a normative connotation which easily leads to confusion. For example, lower female wages would suggest that hours worked by females have a lower 'quality' than hours worked by males. Instead we prefer to use the more positive concept of 'labor composition'.

[48] See Timmer *et al.* (2007a).

with $\bar{v}_j = \frac{1}{2}[v_{j,c} + v_{j,AC}]$ and $v_{j,c}$ the share of asset type j in total nominal capital compensation in country c, $v_{j,AC} = 1/N\sum v_{j,c}$ the average compensation share of capital asset j over all countries N and $S_{j,AC} = 1/N\sum S_{j,c}$, the average stock of asset j. This mirrors equation (A6). Similar indices can be constructed for labor services inputs and intermediate inputs. Gaps in multi factor productivity levels can be derived by subtracting the compensation-weighted relative inputs from relative output as follows (industry and time subscript suppressed for convenience):

$$\ln\frac{A_c^Y}{A_{AC}^Y} = \ln\frac{Y_c}{Y_{AC}} - \bar{v}^X \ln\frac{X_c}{X_{AC}} - \bar{v}^K \ln\frac{K_c}{K_{AC}} - \bar{v}^L \ln\frac{L_c}{L_{AC}} \tag{A11}$$

with v's the input shares in gross output averaged between country c and the average country *AC*. A comparison between two countries, say Germany and the US, can be made indirectly: by first comparing each country with the average country and then comparing the differences in German and US levels relative to the average country.[49]

Output and input PPPs

A level accounting approach to output and productivity comparisons has not been widely applied, which is primarily due to the lack of adequate industry-specific PPPs for output and inputs. PPPs are needed to adjust output and inputs for differences in relative price levels between countries. This is true, even when countries have a common currency unit, such as the euro. For example, when the price of a haircut is 10 euro in Portugal against 15 euro in Germany, the Portuguese price level is 67% of that in Germany and this should be taken into account.[50] This price adjustment is often done by means of GDP PPPs (Purchasing Power Parities) which reflect the average expenditure prices in one country relative to another. GDP PPPs are widely available through the work of the OECD and Eurostat. However, it is well-recognized that the use of GDP PPPs, which reflect expenditure prices of *all* goods and services in the economy, can be misleading when used to convert industry-level output. For example, Bernard and Jones (2001) stated that '. . . research is needed to construct conversion factors appropriate to each sector and that research relying on international comparisons of sectoral productivity and income should proceed with caution until these conversion factors are available' (p. 1169). Until recently, no comprehensive set of industry-level PPPs was available. As an alternative, some studies resorted to the use of 'adjusted' expenditure prices as a proxy for prices for industry output (see e.g. Nicoletti and Scarpetta, 2003). In this paper we make use of a new and comprehensive

[49] Note that the same assumptions as for the growth accounts underlie the level accounts. In particular the assumption of constant returns to scale might be less plausible when comparing countries rather than developments over time. This might be important if one wants to argue that low productivity in services in Europe is in part driven by lack of economies of scale. This can only be tested through a parametric exercise which is outside the scope of this paper. If economies of scale are important at the country level then the measured productivity levels of small countries are underestimated.

[50] Engel and Rogers (2004) found a significant dispersion in prices in the euro area countries, even after introduction of the euro.

dataset of industry PPPs for 1997, in combination with a benchmark set of Supply and Use tables. PPPs for value added are constructed by double deflation of gross output and intermediate inputs within a consistent input–output framework. In addition, relative price ratios for labor and capital input are developed. For a full discussion of the new industry output PPPs, the reader is referred to Timmer, Ypma and van Ark (2007b). For the integration of gross output PPPs and the derivation of input PPPs in a level accounting framework, details are spelled out in Inklaar and Timmer (2007b). Below we only present the most important elements of our methodology.

PPPs for gross output are defined from the producer's point of view and are at basic prices, which measures the amount received by the producer for a unit of a good or service produced. These PPPs have partly been constructed by way of unit value ratios for agricultural, mining, manufacturing and transport and communication services. For other industries, PPPs are based on specific expenditure prices from Eurostat and the OECD, which are allocated to individual industries producing the specific item. The value was adjusted from expenditure to producer level with relative transport and distribution margins and by adjusting for differences in relative tax rates. Margins and tax rates were derived from benchmark supply and use tables for 1997. This set of gross output PPPs for 1997, covering 45 industries at (roughly) 2-digit industry level, has been made transitive across countries by applying the multilateral EKS-procedure for a total of 26 countries.[51] For this study the gross output PPPs were then aggregated to the 26 market industries used in this study.

Intermediate input PPPs should reflect the costs of acquiring intermediate deliveries, hence they need to be based on purchasers' prices. Assuming that the basic price of a good is independent of its use, we can use the same gross output PPP for a particular industry, after adjustment for margins and net taxes, to deflate all intermediate deliveries from that industry to other industries. The aggregate intermediate input PPP for an industry is then derived by weighting its intermediate inputs at the gross output PPPs from the delivering industries. Imports are separately identified for which exchange rates are used as PPP, hence assuming no price differences across countries for imported commodities.

To obtain PPPs for capital and labor input, we follow the methodology outlined by Jorgenson and Nishimizu (1978). The PPP for capital services is based on the expenditure PPP for investment from Eurostat and the OECD, adjusted for differences in the user costs between countries. The user cost of capital input depends on the rate of return to capital, the depreciation rate and the investment price change. These data are taken from the capital accounts discussed above. The procedure to obtain a PPP for labor is more straightforward than for capital as it simply involves aggregating relative wages across different labor types using labor compensation for each type as weights. For this purpose we only distinguish between two labor categories: workers

[51] These include 25 OECD countries and Taiwan.

with a university degree or higher, and those without. This limited number of skill types is due to difficulties in matching schooling systems across the various countries.

APPENDIX 3. CRUDE AND SOPHISTICATED MFP MEASURES

The growth accounting methodology has been theoretically motivated by the seminal contribution of Jorgenson and Griliches (1967) and put in a more general input–output framework by Jorgenson, Gollop and Fraumeni (1987).[52] However, the empirical implementation of this methodology for European countries has been scarce. Despite the publication of an OECD handbook on productivity measurement (Schreyer, 2001), which is based on the growth accounting methodology, national statistical institutes (NSIs) have been slow in adopting this methodology and to date, only one European NSI, i.e. Statistics Denmark, has published MFP-measures on a regular basis.[53] The OECD and the Groningen Growth and Development Centre maintain MFP series for aggregate OECD economies, but not at the industry level with the exception of a single study by Inklaar *et al.* (2005) including four European countries (France, Germany, the Netherlands and the United Kingdom).[54] Because of the lack of useful statistics, various scholars have put together ad-hoc databases mostly for the purpose of one single study. The estimates were often based on the OECD Structural Analysis database, STAN (and its predecessor the International Sectoral Database–ISDB) which provides industry-level series on output, aggregate hours worked and aggregate capital stock for a limited group of countries and years. However, MFP measures based on these aggregate concepts of inputs can be seriously biased as will be shown in this appendix. This is unfortunate, given the increased demand and use of industry-level growth accounting statistics for evaluating a wide range of policy areas, including for example outsourcing and international trade, educational policies, investment tax credits and innovation policies. More broadly, MFP statistics are used to study the effects of regulation of product-, labor- and capital-markets on economic growth and inequality. Finally, MFP measures are a crucial ingredient in growth projections used by central banks to set monetary targets.[55]

In Table A2 we indicate that using more sophisticated input measures is not only conceptually appealing, but also leads to measures of MFP which can be radically different from cruder measures which have been used in previous studies. The first column in Table A2 indicates ‘crude’ MFP growth rates averaged over the period 1995–2004 for each country. The crude measure is calculated by subtracting the weighted growth in persons engaged and growth of the capital stock from growth in

[52] See Jorgenson (1995) and Hulten (2001) for an overview.

[53] Several European NSIs are experimenting with growth accounting statistics, including Statistics Netherlands, Statistics Sweden, Statistics Finland and ISTAT (the Italian NSI).

[54] For OECD series, see www.oecd.org/dataoecd/27/39/36396940.xls. For GGDC series, see www.ggdc.nl/dseries/growth-accounting.shtml, described in Timmer and van Ark (2005).

[55] See e.g. Koeniger and Leonardi (2007), Nicoletti and Scarpetta (2003), Griffith *et al.* (2004), Vandenbussche *et al.* (2006) and Jorgenson, Ho and Stiroh (2007).

Table A2. Sensitivity of MFP growth in market services to different input and output measures, averaged across industries, average 1995–2004

	(1) Crude estimate	(2) Effect of accounting for: Changes in average hours worked	(3) Changes in labor composition	(4) Changes in capital composition	(5) Value added/ gross output ratio	(6) = sum (1) to (5) Prefered estimate
Austria	0.2	*0.0*	*–0.2*	*–0.1*	*0.1*	–0.1
Belgium	0.6	*0.0*	*–0.3*	*–0.7*	*0.4*	–0.1
Denmark	0.6	*–0.2*	*–0.3*	*–1.0*	*0.4*	–0.4
Finland	1.9	*0.1*	*0.1*	*–0.1*	*–0.8*	1.3
France	0.9	*0.4*	*–0.4*	*–0.1*	*–0.4*	0.5
Germany	0.1	*0.7*	*0.0*	*–0.1*	*–0.2*	0.4
Italy	–0.5	*0.2*	*–0.1*	*0.2*	*0.2*	–0.1
Netherlands	1.7	*0.4*	*0.0*	*–0.2*	*–0.9*	0.9
Spain	–0.6	*0.0*	*–0.4*	*–0.2*	*0.7*	–0.6
UK	1.5	*0.3*	*–0.4*	*–0.3*	*–0.5*	0.5
US	2.0	*0.1*	*–0.3*	*–0.2*	*–0.6*	1.0

Notes: Column (1), labelled 'Crude', calculates MFP growth by subtracting the (cost-share weighted) growth in persons engaged and the capital stock from growth of value added at constant prices. Figures show average MFP growth for the nine market services for the period 1995–2004. Column (2) shows the effect of accounting for changes in average hours worked by persons engaged. Column (3) shows the effect of accounting for changes in the composition of the workforce (distinguishing workers based on education, age and gender). Column (4) shows the effect of accounting for changes in the composition of capital (distinguishing six types of capital assets). Both composition adjustments recognize that workers with higher wages and capital assets with higher user costs should have a higher marginal product. Column (5) shows the effect of accounting for differences in the use of intermediate inputs. Column (6), labelled 'Preferred', calculates MFP growth by subtracting the (cost-share weighted) growth in hours worked by different types of workers, different types of capital and intermediate inputs from growth of gross output at constant prices. It is equal to the sum of columns (1) through (5).

Source: Calculations by authors on EU KLEMS database, March 2007 (http://www.euklems.net), described in Timmer *et al.* (2007).

value added volumes.[56] This crude measure is used for example by Vandenbussche, Aghion and Meghir (2006) and Färe *et al.* (2006). In the remaining columns, the ingredients for an adjustment of the MFP measure are constructed in a sequential procedure. Each column shows the additional effect on MFP growth rates by taking into account an improvement in a particular input measure. Subsequently, we show the effects of taking into account changes in average hours worked (as e.g. in Nicoletti and Scarpetta, 2003), changes in labor composition (as e.g. in Griffith, Redding and van Reenen, 2004; Cameron, Proudman and Redding, 2005), changes in capital

[56] An additional issue for the growth accounting decomposition not discussed so far, is the calculation of the weights in equations (A2) and (A3). As each input should be weighted by its share in total costs, most studies typically take the compensation of employees as the weight for labor input. However, the labor input weight should also reflect the costs of labor for self-employed. Especially for industries with a large number of self-employed such as retailing, hotels and restaurant and some business services, the share of self-employed can be up to 15 percent. We adjust labor compensation by the ratio of total persons engaged over employees, implicitly assuming that self-employed have a wage similar to employees. The weight of capital is defined as gross value added minus our measure of labor compensation. This will include taxes on production.

composition and accounting for intermediate inputs. By summing up the MFP effects from the four adjustments, our preferred estimate in the last column of Table A2 is derived from the crude MFP estimate.[57]

The overall adjustments made to the crude MFP estimate vary considerable across countries and we find no clear cross-country pattern in the bias. Our preferred estimate is up to 1.0 percentage point lower than the crude estimate for Denmark, the UK and the US, but up to 0.4% higher in Italy and Germany. For example, while on the basis of the crude measures annual US MFP growth is 1.9% higher than in Germany, our preferred estimate indicates a growth advantage of 0.6%. However, although no clear biases can be detected in the overall combined adjustments, the individual component adjustments often have predictable effects. Accounting for changes in hours worked (column 2) leads to higher MFP growth rates in all countries (except Denmark) as hours worked per worker are still declining across Europe. The adjustments for changes in labor composition are often negative, as there is a general shift towards higher-skilled and more experienced workers. The most important adjustment is the shift from a capital measure based on aggregate stocks to capital services. As shown in the main text, the importance of short-lived ICT assets relative to non-ICT assets has increased over time. Consequently, capital service input growth rates are higher than capital stock growth rates in all countries (except for Italy). The final adjustment from a value added based MFP measure to a gross output based MFP measure shows no effect in a particular direction. If value added volume growth is measured as a weighted growth rate of gross output and intermediate input volumes, MFP measured for gross output and MFP as measured for value added are proportional to each other depending on the ratio of gross output over value added as the factor of proportion.[58] This factor will differ across countries, and over time. For example, there is a general tendency towards using more intermediate inputs, especially business services, as firms outsource many of the standardized service activities. This leads to an increase in the ratio of intermediates over gross output which should be accounted for. As can be seen from column (5), this adjustment differs across countries without a clear pattern.

Obviously, our preferred measure is still imperfect as it does not deal with other adjustments which are needed such as changes in capital capacity utilization (which is especially important for short-run analysis), imperfect competition, intra-industry deliveries and intangible capital. The latter refers to the need for including intangible capital measures such as R&D knowledge and organizational capital into the input measures. These adjustments are beyond the scope of the current study, but point to avenues for further research (see e.g. Corrado, Hulten and Sichel (2006) on the measurement of intangibles).

[57] Note that the preferred MFP estimate in this table differs from the one shown in Table 6. While the MFP measure shown here is based on the gross output basis, the one in Table 6 is on a value added basis, see main text.

[58] See Bruno (1984), Jorgenson, Gollop and Fraumeni (1987) or Schreyer (2001) for an extensive discussion.

Table A3. Multi-factor productivity leaders by industry in 1980, 1995 and 2004

Industry	Rank	1980	1995	2004
Motor trade	1st	BEL	BEL	BEL
	2nd	DNK	FRA	GBR
	3rd	FRA	GBR	NLD
Wholesale trade	1st	BEL	GER	GER
	2nd	GER	BEL	NLD
	3rd	FIN	DNK	FIN
Retail trade	1st	DNK	DNK	DNK
	2nd	BEL	GER	GER
	3rd	GER	FRA	FRA
Hotels and restaurants	1st	FRA	GER	AUT
	2nd	GER	AUT	GER
	3rd	DNK	US	US
Transport and storage	1st	NLD	NLD	NLD
	2nd	US	US	US
	3rd	FRA	FRA	FRA
Post and telecommunications	1st	GBR	GBR	GBR
	2nd	US	FRA	FRA
	3rd	BEL	BEL	GER
Financial intermediation	1st	ITA	ITA	ITA
	2nd	US	NLD	BEL
	3rd	ESP	FRA	DNK
Business services	1st	US	US	US
	2nd	ESP	DNK	BEL
	3rd	ITA	GER	DNK
Social and personal services	1st	NLD	DNK	FRA
	2nd	AUT	GER	NLD
	3rd	DNK	NLD	GER

Source: Calculations based on EU KLEMS database, March 2007 (http://www.euklems.net), See Appendix 2.

APPENDIX 4. ROBUSTNESS ANALYSIS

Available at http://www.economic-policy.org

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